MEMORANDUM

To:	EPA
Copy To:	File 80021
From:	J. Lambert, J. Brunelle
Subject:	Olin Chemical Superfund Site: Revised evaluation of DAPL and NDMA to support Feasibility Study review and development of DAPL and groundwater alternatives v5
Date:	July 19, 2019

Nobis Group® (Nobis) has developed this Technical Memorandum (Memo) to support the U.S. Environmental Protection Agency (EPA) review of the Draft Interim Action Feasibility Study (IAFS) (Wood Environment & Infrastructure Solutions [Wood], 2019a) and development of additional alternatives to address dense aqueous phase liquid (DAPL) and highly contaminated groundwater at the Olin Chemical Superfund Site (the Site). This Memo includes a description of each DAPL pool, including the estimated volume of DAPL, a comparison of the DAPL pools to the primary risk driver at the Site (n-nitrosodimethylamine, or NDMA), and an evaluation of the NDMA mass at the Site.

The primary risk driver for groundwater at the Site is NDMA, as concentrations exceed its tapwater regional screening level (RSL) by several orders of magnitude in overburden and bedrock groundwater. The primary source of groundwater contamination at the Site is DAPL. Once the contaminants in DAPL dissolve in groundwater, the contaminated groundwater continues to migrate uncontrolled impacting the downgradient aquifer. Therefore, the uncontrolled highly contaminated groundwater is also an ongoing source causing further aquifer degradation.

Olin has defined DAPL as an aqueous waste material with a combination the following characteristics:

- pH below 4 (this allows metals such as chromium to remain in solution).
- Specific gravity greater than or equal to 1.025.
- A fluid specific conductivity cutoff of 20,600 µmhos/cm (this is what Olin uses as the primary field indicator).
- Ammonia concentrations greater than 1,250 milligrams per liter (mg/L).

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- Chloride concentrations greater than 2,800 mg/L.
- Magnesium concentrations greater than 270 mg/L.
- Sodium concentrations greater than 1,700 mg/L.
- Sulfate concentrations greater than 16,000 mg/L.

DAPL is not a separate phase liquid that can readily be distinguished from the surrounding groundwater. Instead, it is analogous to a brine, with a very high concentration of both anions (sulfate, chloride) and metals (aluminum, calcium, and magnesium), in addition to organic contaminants.

Olin also defines "diffuse groundwater" as the groundwater with specific conductance values between 3,000 and 20,600 µmho/cm.

These definitions are based on data from 1996 and 1998 (Geomega, 1999) and it is not clear if the concentrations have changed in the intervening 20 years. Olin's data from the recent (2019) comprehensive sampling round will be used to revisit and update these definitions.

1.0 DAPL POOL DESCRIPTIONS AND VOLUMES

The DAPL at the Site is primarily located in three pools in bedrock basins. These pools originated at the Olin property, with each pool filling and flowing over the edge of the bowl and into the next basin. The three major pools are:

- The containment area DAPL pool (on Olin property).
- The adjacent off-property DAPL pool on Jewel Drive (the OPWD DAPL pool).
- The Main Street DAPL pool located to the west.

In addition, DAPL from the Main Street pool is believed to have cascaded into and/or migrated via bedrock fractures to the Maple Meadow Brook Wetland (MMBW) to the west, where it appears to have settled into the bedrock fracture network; however, the extent of DAPL accumulation within the MMBW has yet to be fully characterized. See Figure 1 for a plan view and Figure 2 for a cross-section of the DAPL pools.

Nobis has been tasked with estimating the DAPL volume in each DAPL pool. There are four factors to consider when developing an estimate of the DAPL volume:

1. The definition of DAPL: Olin's definition of DAPL is presented above. These definitions are based on data from 1996 and 1998 (Geomega, 1999) and it is not clear if the concentrations have changed in the intervening 20 years.

   The data from the recent comprehensive sampling round will be used to revisit and update these definitions, but for now, Olin's definitions have been accepted. Note that EPA does not have access to the field specific conductivity data.

2. Elevation of the top of DAPL (TOD): The DAPL pools formed by gravity drainage and over time have filled their respective basins. The elevation of the top of DAPL (TOD) is expected to be have a consistent elevation given the long time that the DAPL pools have been in place.

   Most of the monitoring data available to determine the TOD elevation is based on discrete specific conductivity data collected from multi-level wells. The Jewel Drive DAPL pool is instrumented with additional induction logging boreholes that allow for a more continuous profile of the target area; however, the following factors may influence induction logging data:

   - Induction logging data can only be indirectly linked to the DAPL concentrations.
   - Induction logging can be impacted by nearby soil conditions and should be considered an average value across a small area.
   - Precipitates in the soil may skew the induction logging results.

3. Bedrock surface topography: The lower configuration of the DAPL pool is based on the bedrock topography. This assumes that there are no significant open fractures that may capture DAPL (and add volume) and/or drain each DAPL pool.

   Olin has conducted several investigations to characterize the bedrock surface; however, most of the bedrock data are from surface geophysics and direct-push technology (DPT) investigations that do not adequately confirm the bedrock surface. Given the known variance in bedrock topography in the area, it is possible that specific variations in elevation (i.e. bedrock troughs or depressions) may not have been identified; therefore, DAPL volumes may be greater than calculated.

4. Soil porosity: The DAPL pool volume is based on the pore space available in the subsurface; therefore, volume estimates consider the soil porosity. Olin's original DAPL estimates (Amec, 2017) used a porosity of 0.3. The later IAFS (Wood, 2019a) assumed a porosity of 0.23 for poorly graded sands and gravelly sands, and a porosity of 0.25 for silty sands. The IAFS did not describe the proportion of each material or how the porosity values were selected, so Nobis assumed the more conservative estimate of 0.25 that is close to the average of the range of porosities previously used by Olin and is a representative value for Site conditions. Appendix A2 of the OU3 RI Report (Wood, 2019b) used separate porosities for each DAPL pool, ranging from 0.23 (Jewel Drive DAPL pool) to 0.29 (Main Street DAPL pool). Given uncertainties in soil characterization, Nobis has retained the estimate of 0.25 for each pool.

The following subsections describe the potential volumes of each DAPL pool. The calculated DAPL pool volumes are provided in Table 1.

1.1 Containment Area DAPL Pool

The containment area DAPL pool is located south of the industrial area of the Olin property. Figures 3A and 3B provide DAPL pool configurations based on bedrock contours generated by Olin, 2018a and Nobis, respectively.

1.1.1 Available Data

The areal extent of the containment area DAPL pool is approximately 2 acres.

Monitoring points in the CA DAPL pool include:

- One multiport well (MP-1). This well has 16 ports with 1-foot well screens that are located between 0.5 and 1.5 feet apart.
- Five monitoring wells (BR-1, GW-30DR, GW-35S/D, and PZ-24) are located within the DAPL in the containment area. Most of these are conventional monitoring wells with 5- or 10- foot well screens that are too long to effectively determine the TOD elevation.

The bedrock elevations around the containment area is based on a series of borings installed to support the slurry wall design and construction. However, only a few borings (GW-30DR, GW-35D, and PW-2) have been installed within the DAPL area to confirm the bedrock elevations, as

Olin has avoided installing borings that may serve as conduits for DAPL to enter the bedrock. Surface geophysics has not been performed in this area to determine bedrock topography.

1.1.2 Top of DAPL Elevation

The Draft Focused Remedial Investigation (RI) report for DAPL (Amec Foster Wheeler Environment & Infrastructure, Inc. [Amec], 2017) states that the top of this DAPL pool is at 54.5 feet above mean sea level (MSL) and between MP-1 ports 3 and 4; however, based on the reported elevation, that would put the top of the DAPL pool at the center of MP-1 Port 4 (conflicting data).

Nobis reviewed Olin's DAPL data, and specific conductivity and other DAPL parameters (Table 2) are close to the cutoff in MP-1 Port 4. Nobis estimates the TOD to be between 53.9 and 54.9 feet MSL (top and bottom elevations of the Port 4 screen). The revised RI OU3 RI (Wood, 2019) indicates that the elevation is 51 feet bgs, but this may be an error based on other available evidence.

1.1.3 Bedrock topography

Figure 3A provides the bedrock contours starting at the highest estimated DAPL elevation (54.9 feet MSL) using the most recent bedrock contours provided by Wood for this area (Olin, 2018a). Figure 3B provides the bedrock contours developed by Nobis based on available bedrock data and professional judgement (independent evaluation) (Nobis 2018). EPA did not provide separate bedrock contours for the containment area.

1.1.4 DAPL Volume Estimates

Olin's most recent estimate for the Containment Area DAPL Pool is 200,000 gallons (Wood, 2019b).

Nobis' estimated DAPL volume for the containment area based on factors described above ranges from approximately 450,000 gallons to approximately 660,000 gallons, with an average volume of 550,000, or more than double the IAFS estimate. Note that the porosity suggested by Wood, 2019b is the same as the average porosity recommended by Nobis (0.25 Since the TOD elevations calculated by Nobis and Olin are similar, the difference in volume estimates is due to the difference in the capacity of the bedrock bowl, as calculated by Olin and Nobis. See Table 1 for details.

Nobis recommends an estimate of approximately 610,000 gallons to develop costs and time to complete remediation. This estimate uses the volume based on a porosity of 0.25, bedrock contours developed by Nobis and a reasonable maximum top of DAPL elevation to be conservative.

1.2 Jewel Drive DAPL Pool

The OPWD DAPL pool is immediately west of the containment area DAPL pool and at a slightly lower elevation. Figure 4A and Figure 4B provide the configuration of the DAPL pool based on bedrock contours from Olin (AMEC, 2015) and Nobis, respectively. Olin has pumped the OPWD DAPL as part of a pilot test, so two DAPL elevations were calculated separately using the pre-pumping level and the current level.

1.2.1 Available Data

The areal extent of the OPWD DAPL pool is approximately 2.5 acres. The OPWD DAPL pool contains the following evaluation/monitoring points specific to this DAPL pool:

- One multi-port well (MP-2) at the southern edge of the DAPL pool - MP-2 has 16 screened zones that are each 1 foot long. The distance between screens ranges from 0.5 to 2 feet.
- Four traditional monitoring wells with longer screens at the southern and eastern edge of the DAPL pool (MW-26, MW-42S, MW-42D, and MW-76S).
- Two multi-port wells (ML-1 and ML-2 - we do not have elevation information for the ML-1 or ML-2 ports).
- Two induction logging wells (ILW-1 and ILW-2) close to the current extraction well.

A building covers the central portion of the DAPL pool. Surface geophysics and DPT drilling have been performed at the western edge of the pool along Jewel Drive, northwest of the building, and east of the building. The only location within the DAPL pool with bedrock confirmation is GW-42D.

1.2.2 Top of DAPL Elevation

<u>Pre-Pumping Estimates:</u>
Olin has provided two separate pre-pumping estimates for TOD, including:

- In 2017, AMEC estimated the pre-pumping TOD elevation to be 55 feet MSL.

- 2019 Olin figures present the TOD at the midpoint of Port 5 in ML-1 and ML-2 (approximately 54.4 feet MSL).

Nobis estimates TOD somewhere between 55.4 and 54.8' MSL because:

- DAPL was not detected in ML-2, Port 6 (bottom of screen at 55.4 feet MSL).
- 2012 analytical data shows DAPL constituent concentrations in ML-2 Port 5 (top of screen at 54.8 feet MSL).
-

Current TOD Estimates

Olin has provided two separate estimates for current TOD, including:

- The 2018 Conceptual Site Model (CSM) (Olin, 2018) reports TOD between MP-2 ports 1 and 2. (between 46.6' and 48.1' MSL).
- 2019 Figures show TOD at Port 1 in ML-1 and in ML-2 (approximately at 48.9' MSL).

Nobis estimates the TOD to be between 48.9 feet MSL and 49.4 feet MSL, between ML-1 Port 1 and Port 2 because:

- The October 2018 specific conductivity was 31,900 µmho/cm in ML-1 Port 1 (indicating DAPL).
- The October 2018 specific conductivity was 13,200 µmho/cm in ML-1 Port 2 (not DAPL).
- A reasonable maximum TOD is therefore the bottom of the Port 2 well screen (49.4 feet MSL) and a reasonable minimum TOD is the top of the Port 1 well screen (48.9 feet MSL).

1.2.3 Bedrock topography

Figure 4A provides the bedrock contours starting at the highest estimated DAPL elevation (54.9 feet MSL) using contours provided by Wood for the OPWD area. Given the scale of later bedrock figures, we have used the contours provided in the DAPL pilot test report (Amec, 2015) even though it pre-dates other more comprehensive reports. Later reports (such as the OU3 RI - Amec, 2018) appear to maintain the same contours.

Figure 4B provides the bedrock contours developed by Nobis based on available bedrock data and professional judgement (independent evaluation). EPA did not provide separate bedrock contours for the OPWD DAPL pool.

1.2.4 DAPL Volume Estimates

Olin estimated the pre-pumping OPWD DAPL pool volume as 2.5 million gallons (AMEC, 2017). Olin estimated the current OPWD DAPL pool volume as 1 million gallons in the IAFS (Wood, 2019 a), but revised this value to 1.19 million gallons in the Revised OU3 RI (Wood, 2019b).

Nobis's pre-pumping estimate for the OPWD DAPL pool ranges from 2.3 to 3.6 million gallons, with an average value of 2.8 million gallons, including both the Wood (2019a) porosity of 0.23 and Nobis' suggested average porosity of 0.25. Nobis' calculated volume estimate for the current OPWD DAPL pool is 0.9 to 1.4 million gallons, with an average of 1.1 million gallons. Since the TOD elevations calculated by Nobis and Olin are similar, the difference in volume estimates is due to the difference in the capacity of the bedrock bowl and different porosity values. See Table 1 for details.

Nobis recommends an estimate of approximately 1.4 million gallons to develop costs and time to complete remediation. This estimate uses the volume based on bedrock contours developed by Nobis, porosity of 0.25, and a reasonable maximum top of DAPL elevation.

1.3 Main Street DAPL Pool

The Main Street DAPL pool is the furthest west and the largest pool. Figure 5A, Figure 5B, Figure 5C, and Figure 5D provide the configuration of the DAPL pool based on bedrock contours from the OU3 RI, Olin's updated bedrock contours, and bedrock contours provided by EPA and Nobis, respectively.

1.3.1 Available Data

The areal extent of the Main Street DAPL pool is approximately 15 acres. Monitoring points in the Main Street DAPL pool include:

- One multiport well (MP-3) is at the far northern edge of the DAPL pool. MP-3 has 21 screened zones that are each 1 foot long. The distance between screens ranges from 0.5 to 2 feet.

- Eight traditional monitoring wells with 5- to 10-foot screens (GW-44S/D, GW-45S/D, GW-59S/D and GW-70S/D).
- Two water supply wells (Altron B1 and B3).

Bedrock within the Main Street DAPL area has been evaluated with lines of borehole geophysics and DPT borings at the northwest edge of the DAPL pool, along Eames Street (north-central portion of the DAPL pool), immediately east of the northern end of the DAPL pool, and at the southern end of the DAPL pool.

Individual DPT borings have also been installed at a few locations away from these lines. Bedrock has been confirmed with borings in four locations. This DAPL pool has less coverage compared to the two smaller DAPL pools previously discussed.

1.3.2 Top of DAPL Elevation

The Focused DAPL RI Report (Amec, 2017) indicates that the DAPL pool is between 39.0 and 39.5 feet MSL (assumed to be 39.25 feet MSL).

Nobis estimates the TOD to be between 42 and 39.5 feet MSL (bottom of Port 5 screen and bottom of Port 4 screen) because:

- Limited chloride, sulfate, specific conductance, and specific gravity data collected from MP-3 Port 4 (screened from 38.5 and 39.5 feet MSL) exceed the criteria for DAPL (Table 2).
- DAPL was not detected in Port 5.

Nobis' TOD estimate is slightly higher than Olin's TOD estimate.

1.3.3 Bedrock topography

Figure 5A provides the bedrock contours starting at the highest estimated DAPL elevation (42 feet MSL) using contours provided in the OU3 RI (Amec, 2018). Wood later modified these contours based on a purely mathematical correlation with existing data (Olin, 2018b), as shown in Figure 5B. EPA provided bedrock contours (Figure 5C) based on professional judgement and use of available data points (EPA, 2018). Nobis also developed bedrock contours for this area based on available data and professional judgement as shown in Figure 3D.

1.3.4 DAPL Volume Estimates

Olin estimated the Main Street DAPL pool to contain 13 million gallons; however, the estimate provided in Wood, 2019 appears to use the earlier (Amec, 2018) contours and DAPL elevation that have been superseded.

Nobis' calculated DAPL volume estimates for the Main Street DAPL pool (not including the contours included in the OU3 RI [Amec, 2018] that have been superseded) range from approximately 13 to 21 million gallons, with an average of 16 million gallons. Nobis' upper estimate for TOD is higher than that of Olin and used a different bedrock bowl capacity, resulting in a different volume estimate. See Table 1 for details.

Nobis recommends an estimate of approximately 17.5 million gallons to develop costs and time to complete remediation. This estimate uses the volume based on an average porosity of 0.25, bedrock contours developed by EPA, and a reasonable maximum top of DAPL elevation in order to be conservative.

1.4 DAPL in Bedrock

The DAPL volumes provided in Section 1.1.4, 1.2.4, and 1.3.4 are based on quantities in overburden only (above the bedrock surface). The amount of DAPL beneath each of the DAPL pools is currently unknown, as no bedrock wells have been installed directly below any of the DAPL pools.

Olin contends that the quantity of DAPL in the bedrock fractures directly beneath most of the DAPL pools is negligible because the pore space has been filled by precipitates as the DAPL chemistry changes due to contact with less-contaminated bedrock groundwater.

Additional DAPL may be stored with the rock matrix and fractures. If DAPL is present from the bedrock surface up to a depth of 5 feet below the bedrock surface (using the Nobis reasonable maximum DAPL bottom surface area as shown in Table 1) and a bedrock porosity of 0.01 is selected (value between the assumed effective porosity for weathered bedrock (2%) and competent bedrock (0.5%) used in Olin's numeric fracture modeling [Amec, 2018, Appendix H]) the volume of DAPL in bedrock would be:

- Containment Area: 96,386 $feet^2$ x 5 feet x 0.01 = 4,819 ft^3 or 36,051 gallons.
- OPWD (current): 122,043 $feet^2$ x 5 feet x 0.01 = 6,104 ft^3 or 45,662 gallons.
- Main Street: 599,245 $feet^2$ x 5 feet x 0.01 = 29,962 ft^3 or 224,133 gallons.

These should be considered order of magnitude estimates, as the bedrock fracture and matrix porosity is estimated based on literature values and could be significantly different.

2.0 DAPL COMPARISON TO NDMA

The highest concentrations of NDMA were detected in samples from the westernmost Main Street DAPL pool and within the Maple Meadow Brook Wetland (MMBW) (downgradient to the West of the Main Street DAPL pool) as shown in Figure 6. The NDMA concentrations do not perfectly correlate with the known DAPL pool locations.

In a conference call on May 15, 2019 and in a follow-up discussion on May 21, 2019, EPA representatives requested that Nobis provide additional evaluation to determine the potential relationship between NDMA and the DAPL constituents.

2.1 NDMA/DAPL Correlation Evaluation

Table 3 provides a comparison of average NDMA concentrations for different sample groups from locations:

- Within and above each DAPL pool.
- Within the plume core.
- Between the DAPL pools.
- In areas away from identified DAPL pools.

Nobis used NDMA results from the 2010-2012 Remedial Investigation (RI) where available; however, data from previous sampling (2003-2005 and later) were used if NDMA data were not available. If NDMA was detected in multiple samples from the same sampling location, the sample with the highest detected concentrations was included. Table 4 provides the data used to develop the concentrations in Table 3.

Table 3 includes four sample categories for each location, including:

- DAPL according to Olin's definition (specific conductance, chloride concentrations, and/or specific gravity above Olin's criteria).
- One parameter (ammonia, magnesium, sodium, and/or sulfate) detected above Olin's criteria (even though it does not meet Olin's specific conductance, chloride, or specific gravity criteria).
- Conditions do not meet Olin's DAPL criteria, but the specific conductance is above Olin's threshold for diffuse groundwater (greater than 3,000 µmho/cm).
- Conditions do not meet Olin's criteria for DAPL or diffuse groundwater; no individual parameters are within the range associated with DAPL.

Available data for this comparative exercise is limited. As shown in Table 4, none of the samples collected for NDMA analysis were also collected for specific gravity analysis, and only a few samples were collected for ammonia analysis. Findings of the NDMA/DAPL correlation evaluation are as follows:

- NDMA concentrations appeared to vary by up to an order of magnitude within the DAPL pools (and more in the plume core).
- NDMA concentrations within the Containment Area DAPL pool and the Jewel Drive DAPL pool were relatively low compared to those in the Main Street DAPL pool.
- The highest NDMA concentrations were associated with groundwater that did not meet Olin's DAPL definition (especially in the plume core).

2.2 NDMA/DAPL Constituent Correlation Evaluation

The correlation charts in Attachment A compare the NDMA concentrations to those of individual DAPL constituents (chloride, sulfate, specific conductance, magnesium, and sodium). Non-detect values were not included. Other parameters such as ammonia and specific gravity were not included since Olin did not include NDMA analysis with analysis of those constituents.

Findings of the NDMA/DAPL constituent correlation evaluation are as follows:

- Correlation charts suggest that the NDMA concentrations are generally higher with higher concentrations of other parameters; however, the data show variation in trends for different areas.
- The samples from the plume core in the MMBW tend to have a separate trend that is less linear when compared to cations (magnesium and sodium).

2.3 Individual DAPL Indicators: Trends with Depth

Nobis used the multi-level port wells (MP-1 through MP-5) to evaluate DAPL indicator trends with depth because they are the only monitoring points with consistent sampling data at multiple depths. Attachment B provides the concentrations of major anions and cations detected within and above the DAPL pools, as well as downgradient of the DAPL pools. NDMA was not included in this analysis because relatively few NDMA samples were collected for comparison.

Multiport well locations are described below:

- MP-1 (Figure 3A, 3B): Containment Area, close to the center of the DAPL pool (overburden).
- MP-2 (Figure 4A, 4B): Jewel Drive, at the southern edge of the DAPL pool (overburden).
- MP-3 (Figure 5A-D)): Main Street, at the northeast edge of the DAPL pool (overburden).
- MP-4: Immediately downgradient of northeast edge of the Main Street DAPL pool (overburden and bedrock).
- MP-5: Center of MMBW, downgradient of Main Street DAPL pool (overburden and bedrock).

The charts in Attachment B suggest that the DAPL parameters have a generally consistent trend (they increase with depth) within the DAPL pools, with a relatively clear inflection point between less-contaminated groundwater and the DAPL below. However, anomalous spikes in concentration have been observed for iron and sulfate, and to a lesser extent, calcium.

3.0 NDMA MASS ESTIMATE

Nobis calculated the NDMA mass primarily using available NDMA RI data (maximum detected concentration from 2010-2017); however, the most recent detection was used for locations without data from 2010-2017 (i.e. GW-59D, etc.). NDMA data prior 2003 were not included.

Focus areas included concentrations over 11 ng/L, 110 ng/L, 1,100, 5,000 ng/L (an intermediate value to evaluate higher mass estimates), and 11,000 ng/L. These values ranged from 2 to 5 orders of magnitude above the tapwater RSL of 0.11 ng/L.

These areas are shown in Figure 7A for deep overburden and Figure 7B for bedrock. Shallow overburden concentrations were almost entirely below 1,100 ng/L and significantly lower than deeper overburden concentrations; therefore, areas are based on the deep overburden contours.

The NDMA data from the monitoring wells and ports screened entirely within DAPL were included in DAPL mass calculations and excluded from the overburden groundwater mass calculations to produce distinct mass estimates for each media.

Calculated NDMA mass is provided in Table 5 for each area. Table 5 provides calculated NDMA mass is provided for each area and averaged values based on individual well results. Attachment C includes full example calculations.

The mass of impacted media was determined using the area of contamination (based on isoconcentration contours) and multiplying by the height of the impacted zone, the pore space, and the target concentration, and converting the resulting mass to grams.

Table 5 presents contaminant mass for each zone individually (only the mass for the particular range is shown). The following summarizes total mass for each range of concentrations (i.e. the total mass of MMBW NDMA greater than 1,100 ng/L includes the mass of all the zones [216 g + 653 g + 261 g = 1,130 g]):

Table 6A
NDMA Mass for Each Range of Concentrations

Location	> 1.1 ng/L	> 11 ng/L	> 110 ng/L	> 1,100 ng/L	> 5,000 ng/L	> 11,000 ng/L
MMBW Overburden	1,278 g	1,278 g	1,265 g	1,131 g	915 g	261 g
Plume Center Overburden	2,190 g	2,190 g	2,189 g	2,179 g	2,040 g	1,100 g
Plume East Overburden	329 g	329 g	321 g	282 g	175 g	--
GW-413 Overburden	--	--	20 g	7 g	--	--
Bedrock Main Plume	229 g	229 g	224 g	220 g	132 g	49 g
Bedrock Residential Areas	0.2 g	0.1 g	--	--	--	--

Table 6B
Total NDMA Mass Calculations

Concentration	> 1.1 ng/L	> 11 ng/L	> 110 ng/L	> 1,100 ng/L	> 5,000 ng/L	> 11,000 ng/L
Overburden Plume	3,817 g	3,817 g	3,796 g	3,599 g	3,129 g	1,361 g
Bedrock	230 g	229 g	224 g	220 g	132 g	49 g

3.1 Calculation Assumptions

The assumptions carried in the calculations are detailed below.

Area of contamination:
Surface area is based on isoconcentration contours in Figure 7A and Figure 7B. The footprint of the shallow overburden NDMA concentrations generally overlaps with that of the deep overburden concentrations, which are generally equal to or considerably higher than the shallow overburden concentrations. Only the contours used for the calculations (11, 110, 1,1000, 5,000 and 11,000 ng/L) are shown on the figures for clarity.

Overburden areas were divided into three sections (MMBW, plume center, and plume east) that correspond to areas of varying thicknesses of the overburden (deep, moderate, and shallow depths to bedrock). Bedrock groundwater data is extremely sparse, so no effort was made to subdivide the areas other than splitting out the higher-concentration regions downgradient of the Main Street DAPL pool and at the Containment Area.

Zone height:
Zone heights were based on the average data from representative wells shown in Attachment C.

NDMA concentrations in the overburden plume are generally highest close to the bedrock surface. The bottom of the zone was assumed to be bedrock (or the top of the DAPL surface, for monitoring wells located within DAPL pools) and the top of the zone was assumed to be the bottom of the next highest well screen with elevated concentrations. If a higher well screen without elevated concentrations was not available, contamination was assumed to continue to the top of the water table.

Bedrock contamination zones were assumed to extend from the bedrock surface downward. If a lower "clean" sample was not available, the zone height was assumed to be 10 feet below the lowest screen or open interval of the interval with elevated NDMA concentrations.

Pore space:

The overburden pore space was assumed to be 25% of the total volume as described in Section 1.

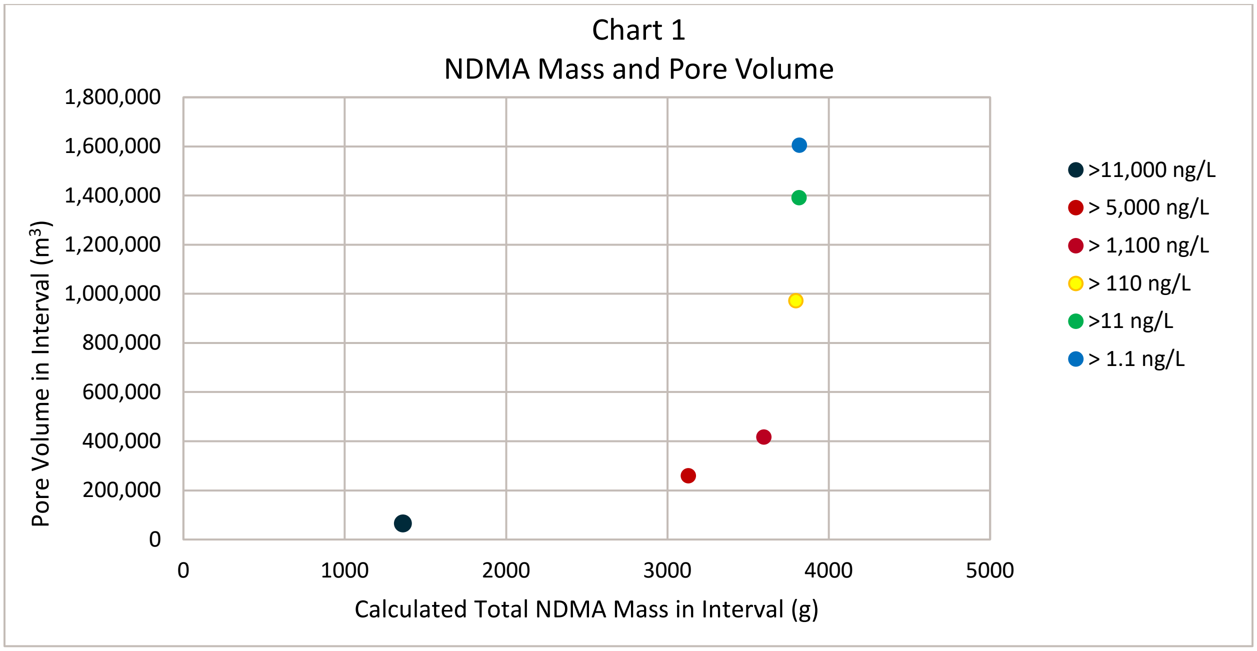
Bedrock fracture and matrix porosity data are generally not available for the area within the 5,000 ng/L contours, and the only wells in this area (BR-1 and GW-202) with borehole geophysics are in bedrock that Olin contends is substantially different from the bedrock in the target area. Nobis selected an estimated total porosity of 1%, as this is between the assumed effective porosity for weathered (2%) and competent bedrock (0.5%) used in Olin's numeric fracture modeling (Amec, 2018, Appendix H).

Concentration:

Nobis used the average maximum NDMA concentrations from 2010-2017 in the wells in each target zone to develop an overall concentration. These representative wells were selected instead of assuming a standard concentration to limit the potential error involved in drawing contour lines based on limited concentration data. Averaged data are included in Attachment C.

3.2 Pore Volume Evaluation

The following chart compares the total overburden NDMA mass and pore volume within each concentration interval shown in Figure 7A.



When the pore volumes are compared to the calculated total NDMA mass, there is a much smaller drop-off in total mass above the 1,100 ng/L contour and to a lesser extent, above the 5,000 ng/L contour. This suggests that the 5,000 ng/L contour would be a reasonable target for NDMA mass removal. Refer to Attachment D for information used to generate Chart 1.

3.3 NDMA Mass Comparison

Nobis calculated the NDMA mass in the DAPL pools using the average estimated DAPL pool volume from Table 1, assumed overburden porosity of 25%, and the average concentrations from Table 3. See Table 7 for calculations.

The highest calculated NDMA mass from each DAPL pool is as follows:

- Total mass in the Main Street DAPL pool is 980g.
- Total mass in the OPWD DAPL pool is 14g.
- Total mass in the Containment Area DAPL pool is 2.4g.

The NDMA mass calculated in the DAPL pools (Figures 3 through 5) can be compared to the NDMA mass in overburden groundwater (Figure 7a) is as follows:

- Total mass in groundwater within the 11,000 ng/L contours is 1,361g.
- Total mass within the 5,000 ng/L contour is 3,129g.
- Total mass within the 1,100 ng/L contour: 3,599g.
- Mass within the three DAPL pools: 997g.

The DAPL pools contains less NDMA mass than the NDMA mass in the 3 highly contaminated groundwater plumes listed above.

4.0 REFERENCES

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Table 1
DAPL Volume Calculation
Olin Chemical Superfund Site
Wilmington, Massachusetts

	Bedrock Contour Source	DAPL Bottom Surface Area (sqft)	DAPL Top Surface Area (sqft)	3-D Volume (cu ft)	Assumed Porosity	3-D Pore/ DAPL Volume (cu ft)	3-D Pore/ DAPL Volume (gal)
Containment Area DAPL Pool							
Reasonable Max. Elev.: 54.9 feet MSL	Nobis	96,386	96,253	328,297	0.25	82,074	613,956
	Olin - RI	124,447	124,206	355,398	0.25	88,850	664,639
Olin Elev.: 54.5 feet MSL	Nobis	91,150	91,028	290,846	0.25	72,712	543,918
	Olin - RI	110,688	110,466	308,649	0.25	77,162	577,212
Reasonable Min. Elev.: 53.9 feet MSL	Nobis	83,554	83,449	238,518	0.25	59,630	446,058
	Olin - RI	95,306	95,116	247,163	0.25	61,791	462,226
						Minimum	446,058
						Maximum	664,639
						IAFS DAPL Pool Estimate	200,000
						Revised OU3 RI Pool Estimate	200,000
Jewel Drive (OPWD) DAPL Pool - Pre-Pumping (2012)							
Nobis (average) porosity							
Reasonable Max. Elev: 55.4 feet MSL	Nobis	257,055	255,360	1,931,398	0.25	482,849	3,611,956
	Olin - RI	179,058	177,846	1,440,103	0.25	360,026	2,693,172
Olin Elev.: 54.4 feet MSL	Nobis	243,744	242,100	1,682,439	0.25	420,610	3,146,370
	Olin - RI	170,744	169,546	1,334,758	0.25	333,689	2,496,164
Reasonable Min. Elev.: 54.8 feet MSL	Nobis	249,392	247,728	1,780,418	0.25	445,104	3,329,604
	Olin - RI	170,744	169,546	1,334,758	0.25	333,689	2,496,164
Wood Revised RI porosity							
Reasonable Max. Elev: 55.4 feet MSL	Nobis	257,055	255,360	1,931,398	0.23	444,222	3,322,999
	Olin - RI	179,058	177,846	1,440,103	0.23	331,224	2,477,718
Olin Elev.: 54.4 feet MSL	Nobis	243,744	242,100	1,682,439	0.23	386,961	2,894,661
	Olin - RI	170,744	169,546	1,334,758	0.23	306,994	2,296,471
Reasonable Min. Elev.: 54.8 feet MSL	Nobis	249,392	247,728	1,780,418	0.23	409,496	3,063,235
	Olin - RI	170,744	169,546	1,334,758	0.23	306,994	2,296,471
						Minimum	2,296,471
						Maximum	3,611,956
						Previous estimate	2,500,000
Jewel Drive (OPWD) DAPL Pool - Current							
Nobis (average) porosity							
Reasonable Max. Elev: 49.4 feet MSL	Nobis	122,043	120,669	729,630	0.25	182,408	1,364,500
	Olin - RI	106,261	105,636	593,107	0.25	148,277	1,109,183
Olin Elev.: 48.9 feet MSL	Nobis	116,252	114,964	670,744	0.25	167,686	1,254,375
	Olin - RI	100,852	100,268	541,643	0.25	135,411	1,012,940
Reasonable Min. Elev.: 48.9 feet MSL	Nobis	116,252	114,964	670,744	0.25	167,686	1,254,375
	Olin - RI	100,852	100,268	541,643	0.25	135,411	1,012,940
Wood Revised RI porosity							
Reasonable Max. Elev: 49.4 feet MSL	Nobis	122,043	120,669	729,630	0.23	167,815	1,255,340
	Olin - RI	106,261	105,636	593,107	0.23	136,415	1,020,449
Olin Elev.: 48.9 feet MSL	Nobis	116,252	114,964	670,744	0.23	154,271	1,154,025
	Olin - RI	100,852	100,268	541,643	0.23	124,578	931,905
Reasonable Min. Elev.: 48.9 feet MSL	Nobis	116,252	114,964	670,744	0.23	154,271	1,154,025
	Olin - RI	100,852	100,268	541,643	0.23	124,578	931,905
						Minimum	931,905
						Maximum	1,364,500
						IAFS DAPL Pool Estimate	1,000,000
						Revised OU3 RI Pool Estimate	1,190,000

Table 1
DAPL Volume Calculation
Olin Chemical Superfund Site
Wilmington, Massachusetts

	Bedrock Contour Source	DAPL Bottom Surface Area (sqft)	DAPL Top Surface Area (sqft)	3-D Volume (cu ft)	Assumed Porosity	3-D Pore/ DAPL Volume (cu ft)	3-D Pore/ DAPL Volume (gal)
Main Street DAPL Pool							
Nobis (average) porosity							
Reasonable Max. Elev.: 42 feet MSL	Nobis	599,245	596,242	8,946,572	0.25	2,236,643	16,731,208
	Olin - RI	737,887	735,018	7,634,544	0.25	1,908,636	14,277,552
	Olin - Post RI	911,031	907,158	9,763,713	0.25	2,440,928	18,259,364
	EPA	760,590	754,321	9,372,424	0.25	2,343,106	17,527,605
Reasonable Min. Elev.: 39.5 feet MSL	Nobis	580,432	577,635	7,352,411	0.25	1,838,103	13,749,928
	Olin - RI	625,408	622,996	5,929,004	0.25	1,482,251	11,087,979
	Olin - Post RI	793,946	790,590	7,644,265	0.25	1,911,066	14,295,731
	EPA	696,634	690,785	7,561,840	0.25	1,890,460	14,141,586
Olin Elev.: 39.25 feet MSL	Nobis	577,169	574,394	7,198,686	0.25	1,799,671	13,462,443
	Olin - RI	615,115	612,743	5,774,538	0.25	1,443,634	10,799,107
	Olin - Post RI	782,960	779,647	7,447,988	0.25	1,861,997	13,928,669
	EPA	690,181	684,380	7,389,943	0.25	1,847,486	13,820,117
Wood Revised RI porosity							
Reasonable Max. Elev.: 42 feet MSL	Nobis	599,245	596,242	8,946,572	0.29	2,594,506	19,408,201
	Olin - RI	737,887	735,018	7,634,544	0.29	2,214,018	16,561,960
	Olin - Post RI	911,031	907,158	9,763,713	0.29	2,831,477	21,180,862
	EPA	760,590	754,321	9,372,424	0.29	2,718,003	20,332,022
Reasonable Min. Elev.: 39.5 feet MSL	Nobis	580,432	577,635	7,352,411	0.29	2,132,199	15,949,916
	Olin - RI	625,408	622,996	5,929,004	0.29	1,719,411	12,862,056
	Olin - Post RI	793,946	790,590	7,644,265	0.29	2,216,837	16,583,048
	EPA	696,634	690,785	7,561,840	0.29	2,192,934	16,404,240
Olin Elev.: 39.25 feet MSL	Nobis	577,169	574,394	7,198,686	0.29	2,087,619	15,616,433
	Olin - RI	615,115	612,743	5,774,538	0.29	1,674,616	12,526,965
	Olin - Post RI	782,960	779,647	7,447,988	0.29	2,159,917	16,157,256
	EPA	690,181	684,380	7,389,943	0.29	2,143,083	16,031,336
						Minimum (not including Olin RI values)	13,462,443
						Maximum (not including Olin RI values)	21,180,862
						IAFS DAPL Pool Estimate	13,000,000
						Revised OU3 RI Pool Estimate	13,240,000

Note: 3-D volume calculated using ESRI GIS software based on the bedrock bottom surface and DAPL elevation top surface.

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Containment Area																						
Sample Location			MP-1 #01												MP-1 #02			MP-1 #03				MP-1 #04			
Sample Date			04/18/96	05/23/96	08/11/98	01/20/00	03/25/03	03/29/04	05/03/05	05/17/10		07/20/10	10/20/10	02/09/12	04/18/96	05/23/96	08/11/98	05/23/96		08/11/98	03/25/03	04/18/96	05/23/96	08/11/98	05/13/01
Sample Type			N	N	N	N	N	N	N	N	FD	N	N	N	N	N	N	N	FD	N	N	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	MP-1 #01-19960418	MP-1 #01-19960523	MP-1 #01-19980811	MP-1-1	MP1-#1	MP1-DAPL	MP-1 PORT 1	OC-MP-1 #01-XXX-20100517	OC-MP-1 #01-DUP	MLP-1-1	OC-MP-1 #01-XXX-20101020	OC-MP-1 #1	MP-1 #02-19960418	MP-1 #02-19960523	MP-1 #02-19980811	MP-1 #03-19960523	MP-1 #03 DUP	MP-1 #03-19980811	MP1-#3	MP-1 #04-19960418	MP-1 #04-19960523	MP-1 #04-19980811	MP-1-4
Total Metals																									
Aluminum	ug/L						2560000			1700000	1800000		1800000	1700000							1750000				
Calcium	mg/L						133			630	660		590	530							121				
Iron	ug/L						678000			3000000	3100000		3100000	3300000							148000				
Magnesium	mg/L	270					1930			1600	1600		1500	1500							1310				
Sodium	mg/L	1700					24600			23000	24000		21000	27000							2200				
Dissolved Metals																									
Aluminum	ug/L		1800000	2100000	840000	463000			2100000			1800000			1500000	1700000	1000000	1800000	1700000	13000000		1200000	1300000	770000	410000
Calcium	mg/L		420	460	140	181			600			600			420	550	160	550	540	180		420	530	430	470
Iron	ug/L		2800000	3400000	2900000	3180000			3300000			2900000			2100000	2300000	2000000	1800000	1800000	1100000		190000	190000	26000	15000
Magnesium	mg/L	270	1500	1800	1600	590			1700			1600			1200	1400	1200	1200	1200	1000		900	1100	610	400
Sodium	mg/L	1700	25000	23000	20000	22600		23800	20000			22000			19000	19000	15000	16000	15000	12000		9300	8900	3400	2300
General Chemistry																									
Chloride	mg/L	2800			18300	18000	1470	18000	590	7600	5800	7900	17000	16000			14400			11500	7960			3100	2700
pH	S.U.					3.72	3.7														3.57				3.61
Specific Conductance	umhos /cm	20600				746000	122000			***96192***			***96722***								81800				12900
Specific Gravity	g/mL	1.025		1.05			1.205		1.11			1.1		1.102		1.07		1.02			1.176		1.01		1.2
Sulfate	mg/L	16000			42700	63000	7490	72000	4700	44000	35000	50000	100000	74000			36800			32600	44400			20000	9800
Dissolved General Chemistry																									
Chloride	mg/L	2800	17000	91000											13000	69000		14000	13000			6400	3900		
pH	S.U.		3.7	3.6											3.7	3.6		3.5	3.5			3.5	3.4		
Specific Gravity	g/mL	1.025																	1.04						
Sulfate	mg/L	16000	74000	73000											64000	72000		59000	59000			42000	31000		

Notes:

1. Only well screens/sampling ports containing at least one sample potentially indicative of DAPL or the next highest port are shown.
2. Non-detect results and data validation flags not shown.
2. Values in ***bold italics*** determined based on review of RI low-flow groundwater sample log sheets.

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Containment Area (cont.)																							
Sample Location			MP-1 #04				MP-1 #05									ML-1 #05										
Sample Date			03/25/03	05/03/05	07/20/10	02/09/12	04/18/96	05/23/96	08/10/98	05/13/01	03/25/03	05/03/05		07/20/10	02/09/12	11/01/12	11/07/12	11/08/12	11/16/12	11/19/12		01/08/13	01/29/13	02/13/13	03/05/13	03/07/13
Sample Type			N	N	N	N	N	N	N	N	N	N		FD	N	N	N	N	N	N	N	N	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	MP1-#4	MP-1 PORT 4	MLP-1-4	OC-MP-1 #4	MP-1 #05-19960418	MP-1 #05-19960523	MP-1 #05-19980810	MP-1-5	MP1-#5	MP-1 PORT 5	MP-1 PORT 5B	MLP-1-5	OC-MP-1 #5	OC-ML-1 PORT 5-20121101	OC-ML-1 PORT 5-20121107	OC-ML-1 PORT 5-20121108	OC-ML 1 PORT 5-20121116	OC-ML 1 #5	OC-ML 1 PORT 5-20121119	OC ML1 PORT 5-20130108	OC ML1 PORT 5-20130129	OC ML1 PORT 5-20130213	OC-ML1 PORT 5-20130305	OC-ML1 PORT 5-20130307
Total Metals																										
Aluminum	ug/L		354000			46000					40600				11000											
Calcium	mg/L		506			460					473				380	310	290	280	290	300	300	300	310	310	270	270
Iron	ug/L		10800			9400					6310				12000	160000 ^	140000 ^	140000 ^	140000	140000	130000	110000	99000	91000	70000	66000
Magnesium	mg/L	270	324			130					77.2				31											
Sodium	mg/L	1700	1840			880					624				390	1700	1500	1500	1500	1500	1500	1200	1100	1000	890	850
Dissolved Metals																										
Aluminum	ug/L			140000	40000		78000	110000	26900	11000		9300	9600	9500												
Calcium	mg/L			450	360		260	440	404	390		430	440	385												
Iron	ug/L			2600	4500		5700	6500	2040	10000		1700	1700	8450												
Magnesium	mg/L	270		270	110		96	150	32.1	20		100	100	27.5												
Sodium	mg/L	1700		1300	640		830	800	148	160		560	570	365												
General Chemistry																										
Chloride	mg/L	2800	2040	110	820	860			232	260	564	490	210	185	220	1800	1600	1600	1400	1500		1000	880	900	720	670
pH	S.U.		3.62							3.71	3.97															
Specific Conductance	umhos /cm	20600	19200							3360	9410															
Specific Gravity	g/mL	1.025	1.175	1.01	1.03	1.008				1	1	1.01	1	1.02	1.004											
Sulfate	mg/L	16000	9950	790	5800	4400			2600	2000	3510	3900	300	3000	2400	7700	7400	7300	6600	7700		4500	4100	4300	4300	4100
Dissolved General Chemistry																										
Chloride	mg/L	2800																								
pH	S.U.																									
Specific Gravity	g/mL	1.025																								
Sulfate	mg/L	16000																								

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Jewel Drive																						
Sample Location			ML-2 #05		ML-2 #10											MP-2 #01									
Sample Date			10/25/12	11/06/12	10/26/12	11/01/12	11/07/12	11/08/12	11/13/12	11/16/12	11/19/12	11/27/12	01/07/13	01/28/13	02/12/13	05/20/96	08/12/98	05/14/01	07/25/02	03/27/03	07/31/03	03/30/04	05/02/05	07/19/10	01/10/12
Sample Type			N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	OC-ML-2 PORT 5-20121025	OC-ML-2 PORT 5-20121106	OC-ML-2 PORT 10-20121026	OC-ML-2 PORT 10-20121101	OC-ML-2 PORT 10-20121107	OC-ML-2 PORT 10-20121108	OC-ML-2 PORT 10-20121113	OC-ML 2 PORT 10-20121116	OC-ML 2 PORT 10-20121119	OC-ML 2 PORT 10-20121127	OC ML2 PORT 10-20130107	OC ML2 PORT 10-20130128	OC ML2 PORT 10-20130212	MP-2 #01-19960520	MP-2 #01-19980812	MP-2-1	MP-2 DAPL	MLP2-#1	MP2-1-20030731	MP2-DAPL	MP-2 PORT 1	MLP-2-1	OC-MP-2 #1
Total Metals																									
Aluminum	ug/L																			2040000					1900000
Calcium	mg/L		300	290	16	16	16	16	16	16	16	17	17	17	19					616					510
Iron	ug/L		150000	150000 ^	140 ^	100 ^	110	71	78	68	72	92	200	34						2420000					2000000
Magnesium	mg/L	270																		1210					1200
Sodium	mg/L	1700	2000	1600	140	140	140	150	140	150	140	150	130	130	120				20100	19100					22000
Dissolved Metals																									
Aluminum	ug/L															1600000	550000	620000					2200000	1900000	
Calcium	mg/L															440	200	49					570	570	
Iron	ug/L															1600000	2200000	980000					2200000	2000000	
Magnesium	mg/L	270														940	1300	500					1300	1300	
Sodium	mg/L	1700														24000	25000	7200				23500	21000	20000	
General Chemistry																									
Chloride	mg/L	2800	2000	1700	260	260	260	250	250	260	250	270	190	190	190		17903	28800		18800	6850	19000	4300	13000	16000
pH	S.U.																	3.54		3.51	3.46				
Specific Conductance	umhos /cm	20600																28500		105000	198000				
Specific Gravity	g/mL	1.025														1.07		1.1		1.09			1.11	1.1	1.1
Sulfate	mg/L	16000	7700	47	49	53	51	49	50	47	48	47	41	30	35		43100	95000	73400	66200	77100	71000	20000	71000	72000
Dissolved General Chemistry																									
Chloride	mg/L	2800														17000									
pH	S.U.															3.4									
Specific Gravity	g/mL	1.025																							
Sulfate	mg/L	16000														77000									

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Jewel Drive (cont.)																									
Sample Location			MP-2 #02			MP-2 #03			MP-2 #04									MP-2 #06										
Sample Date			05/20/96	08/12/98	03/27/03	05/20/96	08/12/98	03/27/03	05/20/96	08/12/98	05/14/01	03/27/03	05/02/05	07/19/10	01/10/12	10/26/12	11/02/12	05/20/96	08/12/98	03/27/03	03/30/04	05/02/05	07/19/10	01/10/12	11/16/12	01/09/13	01/30/13	05/20/96
Sample Type			N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	MP-2 #02-19960520	MP-2 #02-19980812	MLP2-#2	MP-2 #03-19960520	MP-2 #03-19980812	MLP2-#3	MP-2 #04-19960520	MP-2 #04-19980812	MP-2-4	MLP2-#4	MP-2 PORT 4	MLP-2-4	OC-MP-2 #4	OC-MP-2 PORT 4-20121026	OC-MP-2 PORT 4-20121102	MP-2 #06-19960520	MP-2 #06-19980812	MLP2-#6	MP2-DIFF	MP-2 PORT 6	MLP-2-6	OC-MP-2 #6	OC-MP2 #6	OC MP2 PORT 6-20130109	OC MP2 PORT 6-20130130	MP-2 #07-19960520
Total Metals																												
Aluminum	ug/L				2020000			1740000				1240000			430000					575000				14000				
Calcium	mg/L				632			573				538			390	230	240			499				130	70	98	98	
Iron	ug/L				1600000			1170000				825000			560000	270000 ^	250000 ^			367000				66000	33000	40000	40000	
Magnesium	mg/L	270			1080			929				675			280					330				43				
Sodium	mg/L	1700			18900			12400				8620			4900	2500	2500			3560				1000	580	670	660	
Dissolved Metals																												
Aluminum	ug/L		1500000	770000		1100000	1100000		1200000	1600000	1400000		1100000	460000				39000	1100000			250000	19000					760
Calcium	mg/L		410	210		340	270		390	230	260		480	410				120	450			320	74					7.1
Iron	ug/L		1100000	1200000		1000000	1300000		1100000	1100000	1000000		820000	520000				44000	290000			320000	51000					2600
Magnesium	mg/L	270	1100	1100		850	960		770	810	770		610	310				48	540			160	34					2.4
Sodium	mg/L	1700	22000	26000		18000	18000		15000	13000	13000		7700	4700				700	6000		718	2500	700					74
General Chemistry																												
Chloride	mg/L	2800		16828	15800		13710	12300		11398	13800	8800	2700	2500	3500	3600	3500		5333	3570	610	2300	730	720	2800	530	490	
pH	S.U.				3.44			3.58			3.72	3.7								4								
Specific Conductance	umhos /cm	20600			148000			79200			24100	56800								22400								
Specific Gravity	g/mL	1.025	1.08		1.1	1.06		1.107	1.06		1.1	1.068	1.05	1.25	1.03			0.995		1.032		1.02	1.01	1.008				0.962
Sulfate	mg/L	16000		42800	60800		35900	3340		31100	65000	31700	12000	18000	18000	18000	18000		24000	12000	2700	9000	3500	3700	2600	2200	2000	
Dissolved General Chemistry																												
Chloride	mg/L	2800	16000			14000			11000									500										500
pH	S.U.		3.4			3.5			3.7									4.3										4.3
Specific Gravity	g/mL	1.025																1.01										1.01
Sulfate	mg/L	16000	71000			62000			52000									2500										2500

DAPL Pool			Jewel Drive (cont.)																									
Sample Location			MP-2 #07						MP-2 #08			MP-2 #09								MP-2 #10							MP-3	
Sample Date			08/11/98	05/14/01	07/25/02	03/27/03	06/07/10	10/25/10	05/20/96	08/11/98	03/27/03	05/20/96	08/11/98	05/14/01	03/27/03	07/31/03	05/02/05	07/19/10	01/10/12	05/20/96	08/11/98	05/14/01	03/27/03		05/02/05	07/19/10	05/22/96	08/13/98
Sample Type			N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	FD	N	N	N	N	N	FD	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	MP-2 #07-19980811	MP-2-7	MP-2 DIFFUSE	MLP2-#7	OC-MP-2 #07-XXX-20100607	OC-MP-2 #07-XXX-20101025	MP-2 #08-19960520	MP-2 #08-19980811	MLP2-#8	MP-2 #09-19960520	MP-2 #09-19980811	MP-2-9	MLP2-#9	MP2-9-20030731	MP-2 PORT 9-20050502	MLP-2-9	OC-MP-2 #9	MP-2 #10-19960520	MP-2 #10-19980811	MP-2-10	MLP2-#10	MLP50-#1 DUP	MP-2 PORT 10	MLP-2-10	MP-3 #01-19960522	MP-3 #01-19980813
Total Metals																												
Aluminum	ug/L					16300	15000	3000			6990				5980				7400				1080	1010				
Calcium	mg/L					165	50	37			118				107				75				27.4	26.2				
Iron	ug/L					62000	37000	19000			39300				33500				40000				7380	7010				
Magnesium	mg/L	270				47	20	12			32				31.3				25				6.83	6.59				
Sodium	mg/L	1700			1030	481	520	330			364				291				640				84.3	77.5				
Dissolved Metals																												
Aluminum	ug/L		700000	350000					1400	570000		260	520000	250000			34000	5100		290	43000	30000			470	13000	1500000	1600000
Calcium	mg/L		350	350					8.6	320		8.6	230	290			130	32.5		12	57	62			24	53	520	220
Iron	ug/L		120000	340000					3000	140000		2100	130000	280000			87000	19000		4300	38000	60000			10000	32000	1800000	1500000
Magnesium	mg/L	270	360	230					2.5	300		1.9	280	170			49	14		3.3	30	29			6.7	23	930	890
Sodium	mg/L	1700	3400	4100					53	3000		45	3000	3000			810	355		39	510	650			140	480	12000	11000
General Chemistry																												
Chloride	mg/L	2800	3570	5040		514	570	360		3161	375		3086	4140	362	2250	720	395	760		28.4	940	87.8	84.5	260	530		11559
pH	S.U.			3.87		4.3					4.8			3.95	4.67	4.01						4.52	5.06	5.02				
Specific Conductance	umhos /cm	20600		15000		4980	***5053***	***3970***			3760			13300	4360	36900						4800	1090	1080				
Specific Gravity	g/mL	1.025		1.2		1.001					1	0.964		1.2	1		1.01	1	1.004			1	0.997	0.998	1	1	1.04	
Sulfate	mg/L	16000	24000	12000	2700	9000	3500	3700					16300	10000	1230	7960	3300	1550	2200		2000	2400	363	346	790	2200		22400
Dissolved General Chemistry																												
Chloride	mg/L	2800																									12000	
pH	S.U.																										3.6	
Specific Gravity	g/mL	1.025																										
Sulfate	mg/L	16000																									48000	

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Main Street																						
Sample Location			#01		MP-3 #01		MP-3 #02				MP-3 #03				MP-3 #04						MP-3 #05			
Sample Date			03/31/04	05/04/05	10/11/11	04/17/12	05/22/96	08/13/98	05/15/01	03/26/03	05/22/96	08/13/98	05/04/05	01/11/12	05/22/96	08/13/98	05/15/01	03/26/03	05/04/05	01/11/12	05/21/96	08/13/98	05/04/05	01/11/12
Sample Type			N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	MP3-DAPL	MP3 PORT 1	OC-MP-3 #01-XXX-20111011	OC-MP-3 #01-XXX-20120417	MP-3 #02-19960522	MP-3 #02-19980813	MP-3-2	MLP3-#2	MP-3 #03-19960522	MP-3 #03-19980813	MP3 PORT 3	OC-MP-3 #3	MP-3 #04-19960522	MP-3 #04-19980813	MP-3-4	MLP3-#4	MP3 PORT 4	OC-MP-3 #4	MP-3 #05-19960521	MP-3 #05-19980813	MP3 PORT 5	OC-MP-3 #5
Total Metals																								
Aluminum	ug/L				1400000	1600000				1800000				630000				252000		64000				4300
Calcium	mg/L				480	550				127				390				389		450				170
Iron	ug/L				2000000	2200000				1900000				20000				9590		3300				1200
Magnesium	mg/L	270			880	1000				913				410				252		130				29
Sodium	mg/L	1700			12000	13000				10200				4600				2260		1500				730
Dissolved Metals																								
Aluminum	ug/L			1700000			1400000	1400000	1100000		930000	980000	1100000		450000	410000	300000		370000		200000	200000	230000	
Calcium	mg/L			580			530	160	75		460	180	510		440	360	390		440		300	230	290	
Iron	ug/L			2200000			1800000	1400000	1600000		520000	180000	150000		75000	21000	12000		10000		20000	15000	9800	
Magnesium	mg/L	270		1000			830	720	660		600	570	620		340	280	260		320		170	170	210	
Sodium	mg/L	1700	11100	13000			12000	9000	65000		6800	7100	5700		2900	2100	2300		2600		1600	1500	1800	
General Chemistry																								
Chloride	mg/L	2800	12000	3200	11000	11000		8650	13320	9280		5183	540	2400		2650	4020	2830	24000	960		1978	430	820
pH	S.U.								3.72	3.71							3.94	4 J						
Specific Conductance	umhos /cm	20600			***65179***	***57005***			22900	79000							13200	31200						
Specific Gravity	g/mL	1.025		1.06			1.02		1	1.17	1.02		1.03	1.028	0.967				1.02		0.995		1	1.004
Sulfate	mg/L	16000	47000	4500	45000	45000		28800	32000	34100		23400	5600	19000										
Dissolved General Chemistry																								
Chloride	mg/L	2800					5000				3400				1900						1500			
pH	S.U.						3.6				3.6				3.9						4.2			
Specific Gravity	g/mL	1.025													1.01						1.01			
Sulfate	mg/L	16000					38000				24000				12000						7100			

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Main Street (cont.)																							
Sample Location			MP-3 #06					MP-3 #07									GW-44D									
Sample Date			05/21/96	08/13/98	05/15/01	03/26/03	03/31/04	05/21/96	08/13/98	05/15/01	03/26/03		05/04/05	10/11/11	01/11/12	04/17/12	01/27/92	08/12/92	11/10/92	10/17/95	04/10/97	07/07/99	07/21/99	10/12/11		04/17/12
Sample Type			N	N	N	N	N	N	N	N	N	FD	N	N	N	N	N	N	N	N	N	N	N	N	FD	N
Sample ID	**Units**	**Olin DAPL Criterion**	MP-3 #06-19960521	MP-3 #06-19980813	MP-3-6	MLP3-#6	MP3-DIFF	MP-3 #07-19960521	MP-3 #07-19980813	MP-3-7	MP3-#7	MP3-#22 DUP	MP3 PORT 7	OC-MP-3 #07-XXX-20111011	OC-MP-3 #7	OC-MP-3 #07-XXX-20120417	GW-44-D-19920127	GW-44-D-19920812	GW-44-D-19921110	GW-44-D-19951017	GW-44-D-19970410	GW-44D-19990707	GW-44D-19990721	OC-GW-44D-XXX-20111012	OC-GW-44D-DUP	OC-GW-44D-XXX-20120417
Total Metals																										
Aluminum	ug/L					55700					20500	20800		110	85 J	130				990000				1200000	1200000	1200000
Calcium	mg/L					193					131	128		37	32	40				360				510	490	500
Iron	ug/L					6230					6620	6690		19 J	29 J	27 J				1800000				2600000	2500000	2500000
Magnesium	mg/L	270				91.6					49.5	50.7		6.5	5.8	7.2				750				1000	990	990
Sodium	mg/L	1700				1140					673	644		340	310	350				10000				11000	10000	12000
Dissolved Metals																										
Aluminum	ug/L		95000	120000	97000			54000	68000	16000			130					1400000	1300000	1300000						
Calcium	mg/L		260	230	220			220	180	45			32					500	480	500						
Iron	ug/L		11000	7000	6600			11000	7300	2900			50 U					2300000	2400000	2500000		2100000	2300000			
Magnesium	mg/L	270	100	120	120			79	78	34			6.7					1000	960	1100						
Sodium	mg/L	1700	1400	3.2	1300		1100	1100	830	440			120					11000	11000	11000						
General Chemistry																										
Chloride	mg/L	2800		1540	2200	15.9	1300		1108	1000	62	57.8	250	640	570	680	8900	9000	12000					10000	9500	11000
pH	S.U.				4.3	4.42 J				4.6	4.65 J	4.62 J										3.89	3.79			
Specific Conductance	umhos /cm	20600			9000	11700				4400	10600	8090		***2214***		***2190***						480000	510000	***63914***		***61080***
Specific Gravity	g/mL	1.025			1	1.12		0.997		1	1	1	1		1.002						1.066					
Sulfate	mg/L	16000															32000	39000	40000			53000	42000	36000	34000	41000
Dissolved General Chemistry																										
Chloride	mg/L	2800	1100					900												13000						
pH	S.U.		4.3					4.4																		
Specific Gravity	g/mL	1.025						1.01																		
Sulfate	mg/L	16000	6900					3900												28000						

Table 2
DAPL Pool Indicator Detected Results
Olin Chemical Superfund Site
Wilmington, Massachusetts

DAPL Pool			Main Street (cont.)																		
Sample Location			GW-45D										GW-59D					GW-70D			
Sample Date			12/13/91	08/10/92	11/12/92	01/13/95	10/17/95	04/10/97	07/07/99	05/19/10	10/27/10		02/08/92	08/06/92		11/10/92		08/10/92	11/12/92	10/22/10	05/18/11
Sample Type			N	N	N	N	N	N	N	N	N	FD	N	N	FD	N	FD	N	N	N	N
Sample ID	**Units**	**Olin DAPL Criterion**	GW-45-D-19911213	GW-45-D-19920810	GW-45-D-19921112	GW-45-D-19950113	GW-45-D-19951017	GW-45-D-19970410	GW-45D-19990707	OC-GW-45D-XXX-20100519	OC-GW-45D-XXX-20101027	OC-GW-45D-DUP	GW-59-D-19920208	GW-59-D-19920806	GW-59-D DUP-19920806	GW-59-D-19921110	GW-59-D DUP-19921110	GW-70-D-19920810	GW-70-D-19921112	OC-GW-70D-XXX-20101022	OC-GW-70D-XXX-20110518
Total Metals																					
Aluminum	ug/L						800000			190000	420000	410000								2000 U	2000 U
Calcium	mg/L						350			440	430	420								350	360
Iron	ug/L						1200000			400000	650000	640000								290000	240000
Magnesium	mg/L	270					540			330	440	430								580	590
Sodium	mg/L	1700					8700			3200	4500	4500								5700	5600
Dissolved Metals																					
Aluminum	ug/L			1100000	1000000	1200000	1100000							820000	800000	720000	680000	2300	1200		
Calcium	mg/L			510	470	690	500							450	450	460	440	430	390		
Iron	ug/L			1300000	1200000	1700000	1500000		1500000					1900000	1700000	1700000	1900000	1100000	1300000		
Magnesium	mg/L	270		670	630	1000	770							680	630	620	630	610	680		
Sodium	mg/L	1700		8900	7900	10000	9300							8400	8900	8000	8100	6000	6300		
General Chemistry																					
Chloride	mg/L	2800	11000	8400	7600					3600	5100	5100	5400	9600	9100	8200	7500	5200	5900	5000	4600
pH	S.U.								3.81												
Specific Conductance	umhos /cm	20600							450000	***24906***	***35888***									***29755***	***37362***
Specific Gravity	g/mL	1.025						1.042													
Sulfate	mg/L	16000	45000	30000	31000				40000	9900	27000	27000	19000	34000	31000	31000	15000	16000	19000	18000	13000
Dissolved General Chemistry																					
Chloride	mg/L	2800				9300	8900														
pH	S.U.																				
Specific Gravity	g/mL	1.025																			
Sulfate	mg/L	16000				39000	32000														

Table 3
DAPL Indicator-NDMA Comparison
Olin Chemical Superfund Site
Wilmington, Massachusetts

Containment Area DAPL Pool

Sample Port/ screen ID	Highest NDMA conc. 2010-2017	NDMA sample date	Average NDMA conc.
SpCond, Chloride and/or SG indicate DAPL			
BR-1	930	06/03/16	1165
MP-1 #1	1400	05/17/10	
Non-Primary Parameter indicate DAPL			
			--
SpCond indicates Diffuse Groundwater			
MP-1 #6	990	10/19/10	990
SpCond indicates Non-Diffuse Groundwater			
MP-1 #17	45	04/09/03	52.5
MP-1 #18	60	03/24/04	

Jewel Drive/OPWD DAPL Pool

Sample Port/ screen ID	Highest NDMA conc. 2010-2017	NDMA sample date	Average NDMA conc.
SpCond, Chloride and/or SG indicate DAPL			
GW-42D	4400	04/01/03	3400
MP-2 #1	2400	03/30/04	
Non-Primary Parameter indicate DAPL			
			--
SpCond indicates Diffuse Groundwater			
MP-2 #7	420	10/25/10	
MP-2 #9	1600	04/09/03	1010
SpCond indicates Non-Diffuse Groundwater			
GW-26S	690	08/14/03	370
GW-76S	49	06/09/10	

Main Street DAPL Pool

Sample Port/ screen ID	Highest NDMA conc. 2010-2017	NDMA sample date	Average NDMA conc.
SpCond, Chloride and/or SG indicate DAPL			
GW-44D	25000	04/17/12	17150
GW-45D	8700	10/27/10	
GW-70D	9900	05/18/11	
MP-3 #1	25000	04/17/12	
Non-Primary Parameter indicate DAPL			
			--
SpCond indicates Diffuse Groundwater			
			--
SpCond indicates Non-Diffuse Groundwater			
GW-45S	1.8	10/27/10	1.8

Plume Core - Main Street to MMBW Center

Sample Port/ screen ID	Highest NDMA conc. 2010-2017	NDMA sample date	Average NDMA conc.
SpCond, Chloride and/or SG indicate DAPL			
GW-83D	8500	11/18/10	8500
Non-Primary Parameter indicate DAPL			
GW-62BR	16000	05/27/10	10566.7
MP-4 #2	5700	12/27/10	
MP-4 #10	10000	04/09/04	
SpCond indicates Diffuse Groundwater			
GW-58D	24000	10/21/10	10860
GW-62BRD	8100	05/27/10	
GW-84D	13000	10/20/10	
GW-85D	4900	06/02/16	
MP-5 #3	4300	05/24/11	
SpCond indicates Non-Diffuse Groundwater			
GW-58S	29	10/21/10	315
GW-62D	365	10/26/10	
GW-62M	37	05/26/10	
GW-83M	840	05/25/11	
GW-83S	120	05/25/11	
GW-84M	8.8	10/20/10	
GW-85M	1000	06/02/16	
MP-4 #12	55	10/27/10	
MP-4 #13	6.3	04/09/03	
MP-4 #14	12	04/09/04	
MP-5 #08	1300	11/19/10	
MP-5 #15	2.5	11/19/10	

Between DAPL Pools

Sample Port/ screen ID	Highest NDMA conc. 2010-2017	NDMA sample date	Average NDMA conc.
SpCond, Chloride and/or SG indicate DAPL			
GW-43D	8600	03/05/04*	8600
Non-Primary Parameter indicate DAPL			
			--
SpCond indicates Diffuse Groundwater			
GW-69D	4000	10/22/10	4000
SpCond indicates Non-Diffuse Groundwater			
GW-43S	23	03/05/04	23

Away from Defined DAPL Pools

Sample Port/ screen ID	Highest NDMA conc. 2010-2017	NDMA sample date	Average NDMA conc.
SpCond, Chloride and/or SG indicate DAPL			
GW-202BRD	1100	05/19/11	1100
Non-Primary Parameter indicate DAPL			
GW-202BRS	5800	05/19/11	3345
GW-202D	890	05/14/10	
SpCond indicates Diffuse Groundwater			
GW-50D	940	10/20/10	1522
GW-55D	1700	10/14/10	
GW-79S	670	05/17/10	
GW-86D	2700	06/02/16	
GW-87D	1600	05/25/11	
SpCond indicates Non-Diffuse Groundwater			
GW-202S	200	05/14/10	259
GW-50S	78	05/20/10	
GW-55S	440	10/14/10	

Notes:
Only detected NDMA concentrations shown.
DAPL = specific gravity > 1.025, specific conductance > 20,600 umhos/cm, ammonia > 1,250 mg/L, chloride > 2,800 mg/L, magnesium > 270 mg/L, sodium > 1,700 mg/L, sulfate > 16,000 mg/L
Diffuse groundwater = 3,000 to 20,600 umhos/cm
2003-2005 data used if no other NDMA available; data prior to 2003 not included

Table 4
Detected DAPL Parameter Summary - Selected Samples
Olin Chemical Superfund Site
Wilmington, Massachusetts

				Containment Area					Jewel Drive							Main Street				
				DAPL		Diffuse	Non-Diffuse		DAPL		Diffuse			Non-Diffuse		DAPL				Non-Diffuse
Sample Location				BR-1	MP-1 #01	MP-1 #06	MP-1 #17	MP-1 #18	GW-42D	MP-2 #01	MP-2 #06	MP-2 #07	MP-2 #09	GW-26	GW-76S	GW-44D	GW-45D	GW-70D	MP-3 #01	GW-45S
Sample Date				06/03/16	05/17/10	10/19/10	04/09/03	03/24/04	03/29/04	03/30/04	03/30/04	10/25/10	04/09/03	08/14/03	06/09/10	04/17/12	10/27/10	05/18/11	04/17/12	10/27/10
Sample Type				N	FD	N	N	N	N	N	N	N	N	N		N	FD	N	N	N
Sample ID	Units	DAPL	***Diffuse***	OC-GW-BR1-XXX-20160603	OC-MP-1 #01-XXX-20100517	OC-MP-1 #06-XXX-20101019	MP-1 PORT 17-20030409	MP1-OVR	GW-42D-20040329	MP2-DAPL	MP2-DIFF	OC-MP-2 #07-XXX-20101025	MP-2 PORT 9-20030409	GW-26-20030814 _00:00	OC-GW-76S-XXX-20100609	OC-GW-44D-XXX-20120417	OC-GW-45D-XXX-20101027	OC-GW-70D-XXX-20110518	OC-MP-3 #01-XXX-20120417	OC-GW-45S-XXX-20101027
Metals and Cyanide																				
Magnesium	mg/L	270			1600	20						12			0.5	990	435	590	1000	2.6
Sodium	mg/L	1700		1300	23500	340						330			15	12000	4500	5600	13000	81
Dissolved Metals and Cyanide																				
Magnesium	mg/L	270												2.77						
Sodium	mg/L	1700							21000	23500	718			74.6						
General Chemistry																				
Ammonia	mg/L	1250		8.7																
Chloride	mg/L	2800		44	6700	130			17000	19000	610	360		50.3	11	11000	5100	4600	11000	170
Specific Conductance	umhos/cm	20600	3000	***26540***	***96192***	***3667***						***3970***		876	220	***61080***	***35888***	***37362***	***57005***	
Specific Gravity	NA	1.025																		
Sulfate	mg/L	16000		28	39500	2700			64000	71000	2700	1600		243	57	41000	27000	13000	45000	63
NDMA																				
N-Nitrosodimethylamine (NDMA)	ng/L			930	1350	990	45	60	4300	2400	1100	420	1600	690	49	25000	6600	9900	25000	1.8

Table 4
Detected DAPL Parameter Summary - Selected Samples
Olin Chemical Superfund Site
Wilmington, Massachusetts

				Plume Core																				
				DAPL				Diffuse					Non-Diffuse											
Sample Location				GW-83D	GW-62BR	MP-4 #02	MP-4 #10	GW-58D	GW-62BRD	GW-84D	GW-85D	MP-5 #03	GW-58S	GW-62D	GW-62M	GW-83M	GW-83S	GW-84M	GW-85M	MP-4 #12	MP-4 #13	MP-4 #14	MP-5 #08	MP-5 #15
Sample Date				11/18/10	05/27/10	10/27/10	04/09/04	10/21/10	05/27/10	10/20/10	06/02/16	05/24/11	10/21/10	10/26/10	05/26/10	05/25/11	05/25/11	10/20/10	06/02/16	10/27/10	04/09/03	04/09/04	11/19/10	11/19/10
Sample Type				N	N	N	N	N	N	N	N	N	N	FD	N	N	N	N	N	N	N	N	N	N
Sample ID	Units	DAPL	***Diffuse***	OC-GW-83D-XXX-20101118	OC-GW-62BR-XXX-20100527	OC-MP-4 #2-XXX	MP4-DIFF	OC-GW-58D-XXX-20101021	OC-GW-62BRD-XXX-20100527	OC-GW-84D-XXX-20101020	OC-GW-85D-20160602	OC-MP-5 #03-XXX-20110524	OC-GW-58S-XXX-20101021	OC-GW-62D-XXX-20101026	OC-GW-62M-XXX-20100526	OC-GW-83M-XXX-20110525	OC-GW-83S-XXX-20110525	OC-GW-84M-XXX-20101020	OC-GW-85M-20160602	OC-MP-4 #12-XXX-20101027	MP-4 PORT 13	MP4-OVR	OC-MP-5 #08-XXX-20101119	OC-MP-5 #15-XXX-20101119
Metals and Cyanide																								
Magnesium	mg/L	270		500	270	300		130	150	190	98	190	2.6	22	9.9	24	9.7	7.9	24	4.9			13	5
Sodium	mg/L	1700		4300	1800	1200		1300	220	1200	640	1100	89	200	150	250	110	79	150	130			190	14
Dissolved Metals and Cyanide																								
Magnesium	mg/L	270																						
Sodium	mg/L	1700					1900															150		
General Chemistry																								
Ammonia	mg/L	1250									200								12					
Chloride	mg/L	2800		4800	1500	2400	210	1600	720	1000	700	1500	180	420	350	380	290	230	320	420		330	460	
Specific Conductance	umhos/cm	20600	3000	***36478***	***10334***	***12939***		***14532***	***3768***	***10496***	***6770***	***11336***	548	2077	1021	2486	1236	840	2486	1437			2345	1009
Specific Gravity	NA	1.025																						
Sulfate	mg/L	16000		20000	5000	4300	780	6300	1300	4900	2400	4500	18	410	76	580	98	26	330	23		51	530	
NDMA																								
N-Nitrosodimethylamine (NDMA)	ng/L			8500	16000	5700	10000	24000	8100	13000	4900	4300	29	365	37	840	120	8.8	1000	55	6.3	12	1300	2.5

Table 4
Detected DAPL Parameter Summary - Selected Samples
Olin Chemical Superfund Site
Wilmington, Massachusetts

				Between Pools			Away from Pools										
				DAPL	Diffuse	Non-Diffuse	DAPL	Diffuse							Non-Diffuse		
Sample Location				GW-43D	GW-69D	GW-43S	GW-202BRS	GW-202BRD	GW-202D	GW-50D	GW-55D	GW-79S	GW-86D	GW-87D	GW-202S	GW-50S	GW-55S
Sample Date				03/05/04	10/22/10	03/05/04	05/19/11	05/19/11	05/14/10	10/20/10	10/14/10	05/17/10	06/02/16	05/25/11	05/14/10	05/20/10	10/14/10
Sample Type				FD	N	N	N	N	N	N	N	N	N	N	N	N	N
Sample ID	Units	DAPL	***Diffuse***	GW-43D-20040305	OC-GW-69D-XXX-20101022	GW-43S-20040305	OC-GW-202BRS-XXX-20110519	OC-GW-202BRD-XXX-20110519	OC-GW-202D-XXX-20100514	OC-GW-50D-XXX-20101020	OC-GW-55D-XXX-20101014	OC-GW-79S-XXX-20100517	OC-GW-86D-20160602	OC-GW-87D-XXX-20110525	OC-GW-202S-XXX-20100514	OC-GW-50S-XXX-20100520	OC-GW-55S-XXX-20101014
Metals and Cyanide																	
Magnesium	mg/L	270			44		180	92	28	20	23	17	58	110	9.5	10	4.7
Sodium	mg/L	1700			560		2400	680	280	220	460	200	340	450	86	45	140
Dissolved Metals and Cyanide																	
Magnesium	mg/L	270															
Sodium	mg/L	1700		2555		92.1											
General Chemistry																	
Ammonia	mg/L	1250											52				
Chloride	mg/L	2800		3200	860	160	2100	930	250	180	400	190	410	580	61	28	110
Specific Conductance	umhos/cm	20600	3000		***7590***		***15320***	***7487***	***4091***	***3087***	***6121***	***3409***	***3530***	***5009***	1503	813	2286
Specific Gravity	NA	1.025															
Sulfate	mg/L	16000		13350	3100	98	9800	2900	2000	1800	2800	1300	1000	2000	580	350	1200
NDMA																	
N-Nitrosodimethylamine (NDMA)	ng/L			7700	4000	23	5800	1100	890	940	1700	670	2700	1600	200	78	440

Notes:

1. sample selection based on sample with highest NDMA concentration 2010-2017 or highest concentration from 2003 or later if no 2010-2017 sample available. Duplicates averaged.

2. values in red determined based on review of RI low-flow groundwater sample log sheets.

Table 5
Estimated NDMA Mass in Groundwater Plume
Olin Chemical Superfund Site
Wilmington, Massachusetts

Area Description	Area (m^2)[1]	Zone Height[2] (ft)	Zone Height (m)	Pore Space[3] (%)	Total Pore Volume (m^3)	Conc.[4] (ng/L)	Mass (g)[5]	Mass (lb)
Overburden Plume Groundwater (does not include DNAPL pool mass)								
MMBW area > 11,000 ng/L	10,530	25	7.6	25%	20,059	13,000	261	0.57
MMBW area 5,000 - 11,000 ng/L	27,285	37	11.3	25%	76,928	8,500	654	1.44
MMBW area 1,100 - 5,000 ng/L	51,474	21	6.4	25%	82,369	2,625	216	0.48
MMBW area 110 - 1,100 ng/L	119,475	47	14.2	25%	423,337	317	134	0.30
MMBW area 11 - 110 ng/L	104,172	33	10.1	25%	261,952	48	12	0.03
MMBW area 1.1 - 11 ng/L	64,262	31	9.4	25%	151,801	2.3	0.3	0.001
Plume Center area > 11,000 ng/L	33,829	17	5.3	25%	44,596	24,667	1,100	2.43
Plume Center area 5,000 - 11,000 ng/L	51,185	25	7.6	25%	97,409	9,650	940	2.07
Plume Center area 1,100 - 5,000 ng/L	20,686	22	6.7	25%	34,678	4,000	139	0.31
Plume Center area 110 - 1,100 ng/L	40,249	21	6.4	25%	64,406	160	10	0.02
Plume Center area 11 - 110 ng/L	25,043	10	3.0	25%	19,083	40	0.8	0.00
Plume Center area 1.1 - 11 ng/L	17,688	11	3.0	25%	13,266	5.8	0.1	0.0002
Plume East area > 5,000 ng/L	10,171	26	7.9	25%	20,073	8,700	175	0.39
Plume East area 1,100 - 5,000 ng/L	36,662	13	4.1	25%	37,379	2,880	108	0.24
Plume East area 110 - 1,100 ng/L	45,378	13	3.9	25%	43,914	890	39	0.09
Plume East area 11 - 110 ng/L	151,356	12	3.7	25%	138,400	55	7.6	0.02
Plume East area 1.1 - 11 ng/L	67,955	9	2.8	25%	48,416	6.4	0.3	0.001
GW-413 Hotspot 1,100 - 5,000 ng/L	2,690	19	5.8	25%	3,895	1,700	6.6	0.01
GW-413 Hotspot 110 - 1,100 ng/L	18,072	17	5.2	25%	23,273	590	14	0.03
Overburden Plume Groundwater Total							3,817	8.4
Overburden Plume Sorbed Mass[6]							1,145	2.5
OVERBURDEN PLUME TOTAL							4,963	10.9
Bedrock Plume Groundwater								
Main Plume > 11,000 ng/L	17,123	59	18.0	1%	3,079	16,000	49	0.11
Main Plume East 5,000 - 11,000 ng/L	5,322	95	29.0	1%	1,541	5,800	8.9	0.02
Main Plume West 5,000 - 11,000 ng/L	42,017	102	30.9	1%	12,999	5,700	74	0.16
Main Plume 1,100 - 5,000 ng/L	210,549	45	13.6	1%	28,719	3,050	88	0.19
Main Plume 110 - 1,100 ng/L	216,790	43	13.0	1%	28,083	130	3.7	0.01
Main Plume 11 - 110 ng/L	368,821	88	26.7	1%	98,455	56	5.5	0.01
Main Plume 1.1 - 11 ng/L	667,477	59	17.9	1%	119,220	3	0.3	0.001
Residential Hotspots 11 - 110 ng/L	13,644	100	30.5	1%	4,159	15	0.1	0.0001
Residential Hotspots 1.1 - 11 ng/L	130,694	100	30.5	1%	39,836	3	0.1	0.0003
Bedrock Plume Groundwater Total							230	0.51
Bedrock Plume Sorbed Mass[7]							2,296	5.1
BEDROCK PLUME TOTAL							2,526	5.6
SITE PLUME TOTAL							7,488	16.5

Notes:

1. Areas based on contours and zones shown in Figure 7A and Figure 7B.
2. Zone height assumed to be difference between lower-concentration screen intervals above (or water table if no higher screen available) and bedrock/top of DAPL for representative wells in each area. See Attachment C.
3. Overburden porosity assumed to be 25%; in the absence of bedrock fracture data in this area, bedrock porosity assumed to be 1% for combined primary (pore) and secondary (fracture) porosity. For simplicity, highly weathered bedrock assumed to be equivalent to overburden.
4. Groundwater concentration based on maximum RI NDMA values (2010-2012) or later results if RI values not available. If no results available 2010-2017, most recent results back to 2003 used. See Attachment C for plume calculations.
5. Mass based on pore volume (m^3) x concentration (ng/L) x 1000L/m^3 x 1µg/1000ng x 1mg/1000µg x 1g/1000 mg (conversion to g)
6. Overburden sorbed mass assumed to be 30% of total mass in pore space.
7. Bedrock sorbed mass assumed to be approximately 10x that of pore (fracture) volume based on similar fracture/ matrix ratio at Eastland Woolen Mill site (similar geology), Nobis, 2005, Table 5-1

Table 7
Estimated NDMA Mass in DAPL Pools
Olin Chemical Superfund Site
Wilmington, Massachusetts

Area Description	Volume (ft^3)[1]	Volume (m^3)	Pore Space[2] (%)	Total Pore Volume (m^3)	Conc.[3] (ng/L)	Mass (g)[4]	Mass (lb)
Overburden DAPL Groundwater							
Containment Area	294,812	8,348	25%	2,087	1,165	2.4	0.005
Jewel Drive (OPWD) current (post-pumping)	596,741	16,898	25%	4,224	3,400	14	0.032
Main Street	8,075,316	228,667	25%	57,167	17,150	980	2.2
Overburden DAPL Groundwater Total						997	2.2
Overburden DAPL Sorbed Mass[6]						299	0.7

Notes:

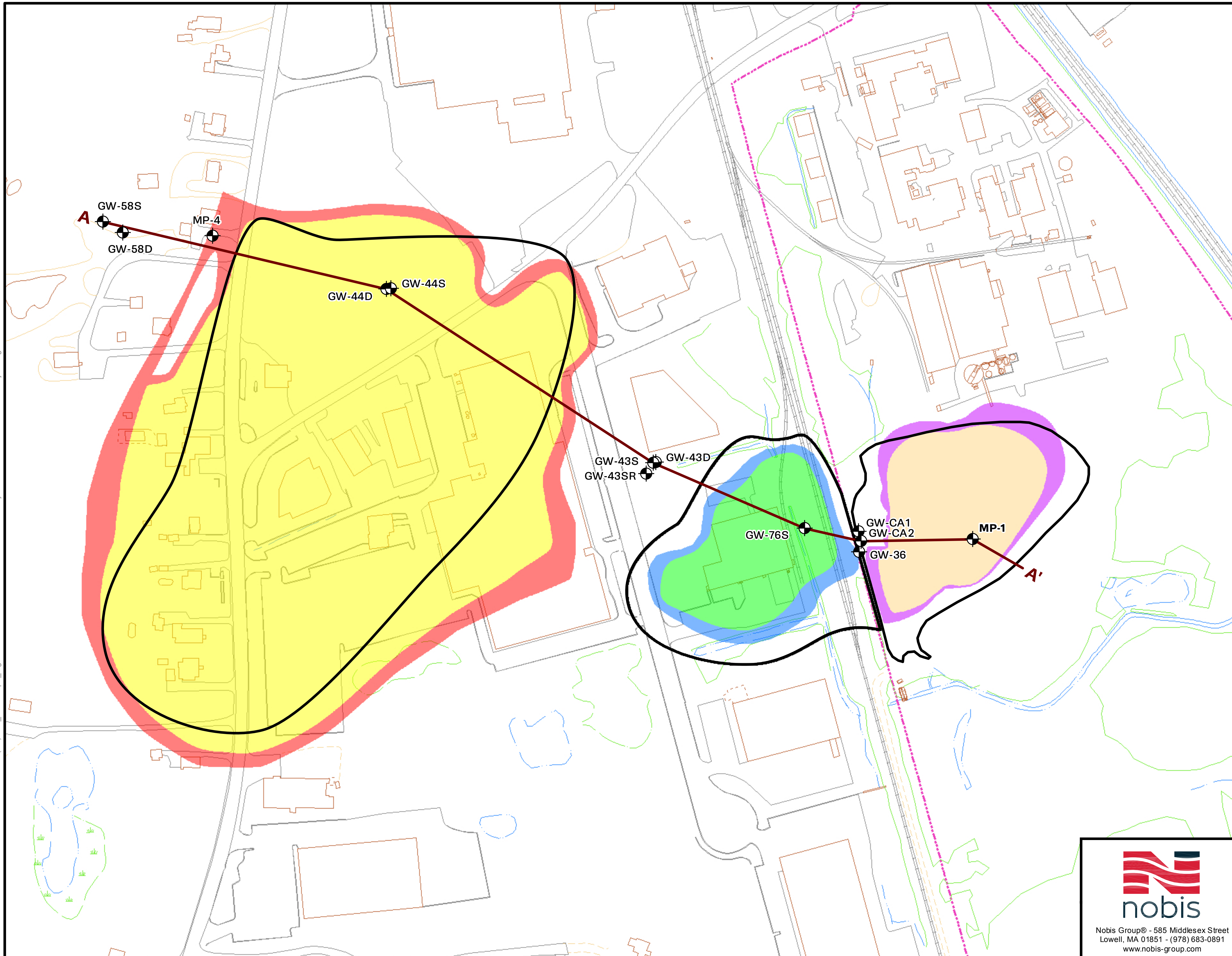
1. Volume based on Table 1 average volume for each DAPL pool ("3-D Volume"). The estimate based on the Olin OU3 RI bedrock topography has been superseded by later Olin bedrock contours and is not included in this average.

2. Overburden porosity assumed to be 25%. For simplicity, highly weathered bedrock assumed to be equivalent to overburden.

3. Groundwater concentration based on maximum RI NDMA values (2010-2012). See Table 3 for average NDMA concentrations for each DAPL pool based on primary indicators (specific conductance, chloride and/or specific gravity)

4. Mass based on pore volume (m^3) x concentration (ng/L) x 1000L/m^3 x 1µg/1000ng x 1mg/1000µg x 1g/1000 mg (conversion to g). See attachment C for example calculations.

5. Overburden sorbed mass assumed to be 30% of total mass in pore space.



Notes:

1. Main Street elevations from Olin, 2018. Slides to support December 10, 2018 team meeting. Provided December 11.

2. Containment Area elvations from Olin, 2018. Results of Containment Area Bedrock Borings, Olin Chemical Superfund Site, (OCSS), Wilmington, MA. May 10.

3. Jewel Drive Elevations from AMEC, 2015. DAPL Extraction Pilot Study Performance Evaluation Report Supplemental Water Level and Hydraulic Analysis. February 5.

4. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

Main St DAPL Pool Extent

- Elev = 39.25
- Elev = 42

Contain. Area DAPL Pool Extent

- Elev = 53.9
- Elev = 54.9

Jewel Dr DAPL Pool Extent

- Elev = 47.1
- Elev = 50.1
- Cross Section Well
- Cross Section Transect
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

N

0 100 200 400 Feet

1 inch = 200 feet

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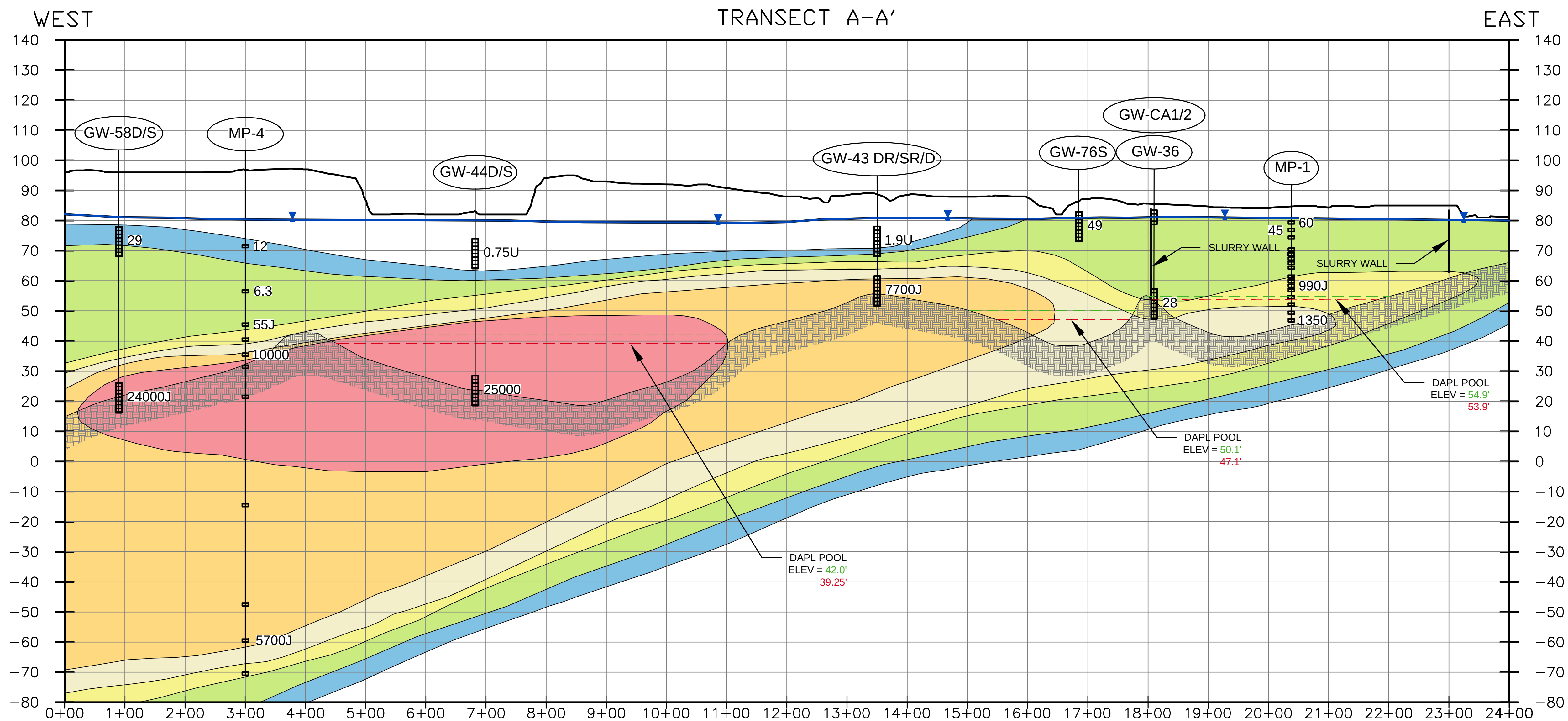
FIGURE 1

DAPL POOL EXTENTS
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSASHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JULY 2018



EXPLORATION LEGEND

B-1 EXPLORATION DESIGNATION

APPROXIMATE EXISTING GROUND SURFACE

TOP OF SCREEN

OBSERVED WATER LEVEL

300 NDMA CONCENTRATION IN ng/L

BOTTOM OF SCREEN

END OF BORING HOLE

MONITORING WELL SCREEN LOCATION

STRATA LEGEND

BEDROCK

MAX TOP DAPL POOL ELEVATION

MIN. TOP DAPL POOL ELEVATION

N-NITROSODIMETHYLAMINE (NDMA) CONCENTRATIONS

- 1.1 - 11 ng/L
- 11 - 110 ng/L
- 110 - 1,100 ng/L
- 1,100 - 5,000 ng/L
- 5,000 ng/L - 11,000 ng/L
- > 11,000 ng/L

HORIZONTAL SCALE IN FEET: 0, 200', 400'

VERTICAL SCALE IN FEET: 0, 40', 80'

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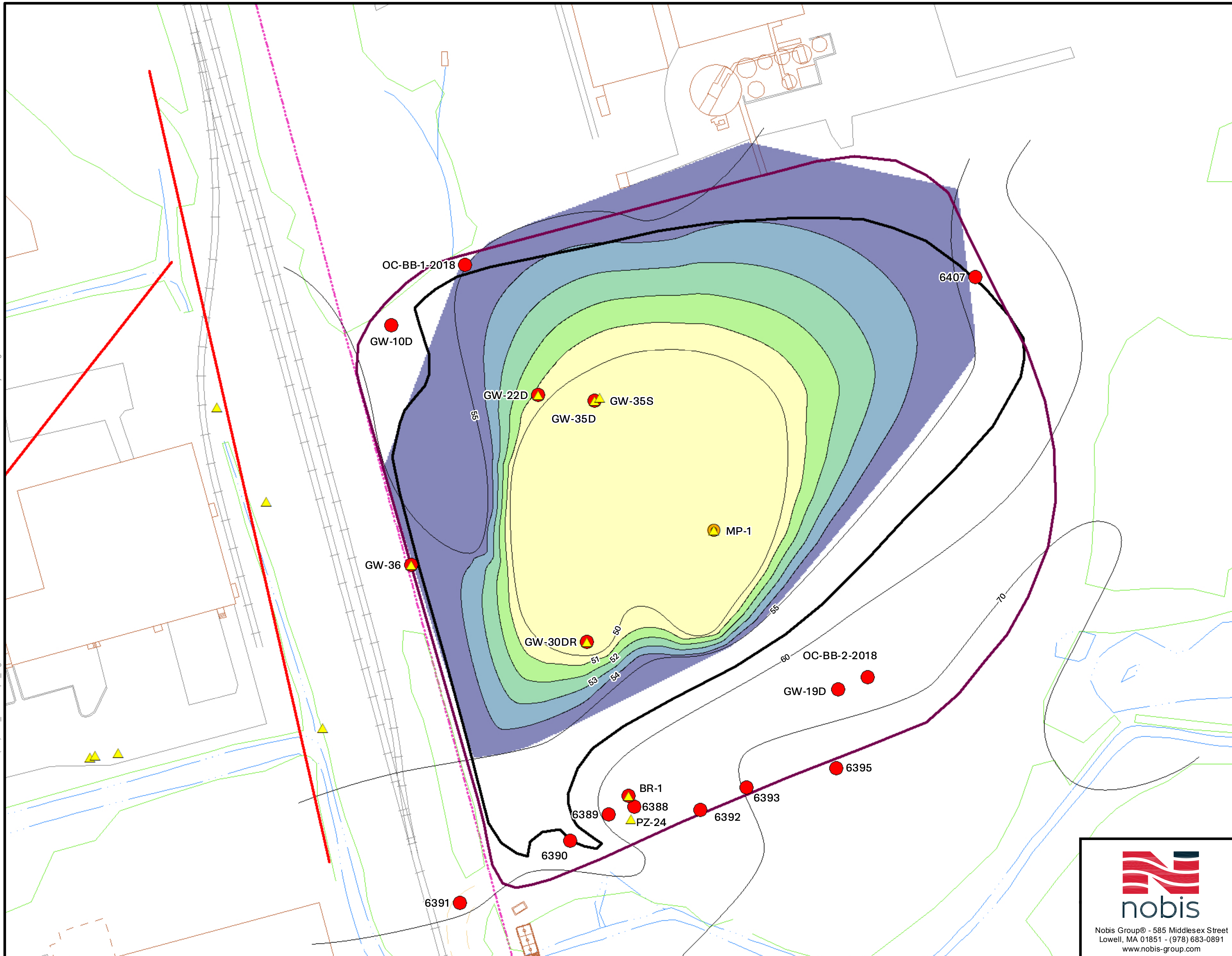
FIGURE 2

CONCEPTUAL SITE MODEL
OLIN CHEMICAL SUPERFUND SITE
51 EAMES STREET
WILMINGTON, MASSACHUSETTS

DRAWN BY:	TWH	CHECKED BY:	JL
PROJECT NO.	80021.10	DATE:	JULY 2019



Notes:

1. Bedrock contours from Olin, 2018. Results of Containment Area Bedrock Borings, Olin Chemical Superfund Site, (OCSS), Wilmington, MA. May 10.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Conventrional Screened Well
- Bedrock Confirmation Location
- Multi-Port Well
- Geophysical Line
- Containment Area
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 50 - 51
- 51 - 52
- 52 - 53
- 53 - 54
- 54 - 55

0 37.5 75 150

Feet

1 inch = 75 feet

N

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FIGURE 3A

WOOD BEDROCK SURFACE
(OLIN, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018

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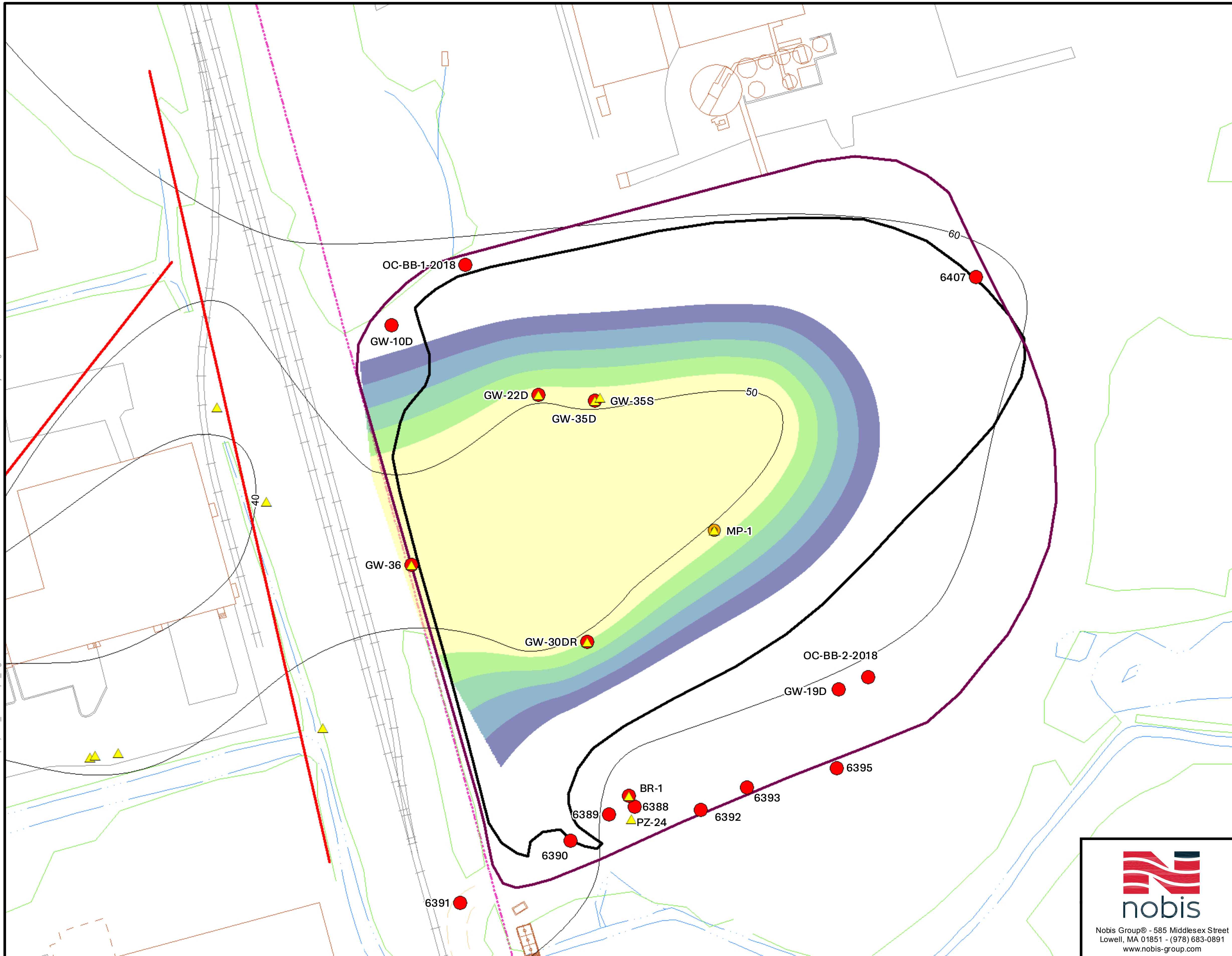

Notes:

1. Bedrock contours from Nobis, 2018. Technical Review Memorandum, Draft Remedial Investigation Report, Operable Unit 3. November 30.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Conventrional Screened Well
- Bedrock Confirmation Location
- Multi-Port Well
- Geophysical Line
- Containment Area
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 50 - 51
- 51 - 52
- 52 - 53
- 53 - 54
- 54 - 55

0 37.5 75 150

Feet

1 inch = 75 feet

N

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FIGURE 3B

NOBIS BEDROCK SURFACE
(NOBIS, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018

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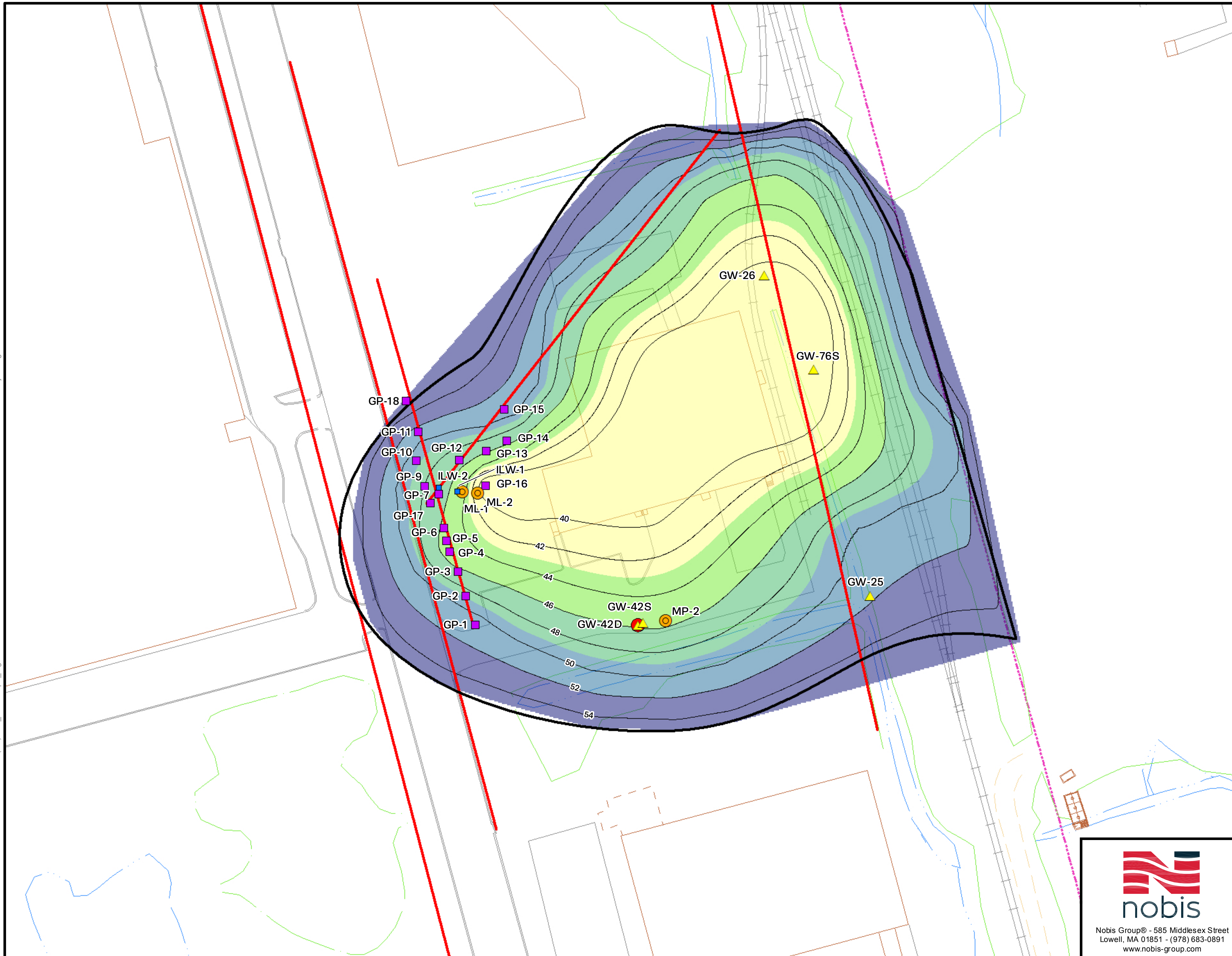

Notes:

1. Bedrock contours from AMEC, 2015. DAPL Extraction Pilot Study Performance Evaluation Report Supplemental Water Level and Hydraulic Analysis. February 5.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Conventional Screened Well
- Bedrock Confirmation Location
- Multi-Port Well
- Induction Logging Well
- DPT Locations
- Geophysical Line
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 40 - 43
- 43 - 46
- 46 - 49
- 49 - 52
- 52 - 56

N

0 37.5 75 150

Feet

1 inch = 75 feet

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FIGURE 4A

WOOD/AMEC BEDROCK SURFACE
(AMEC, 2015)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018

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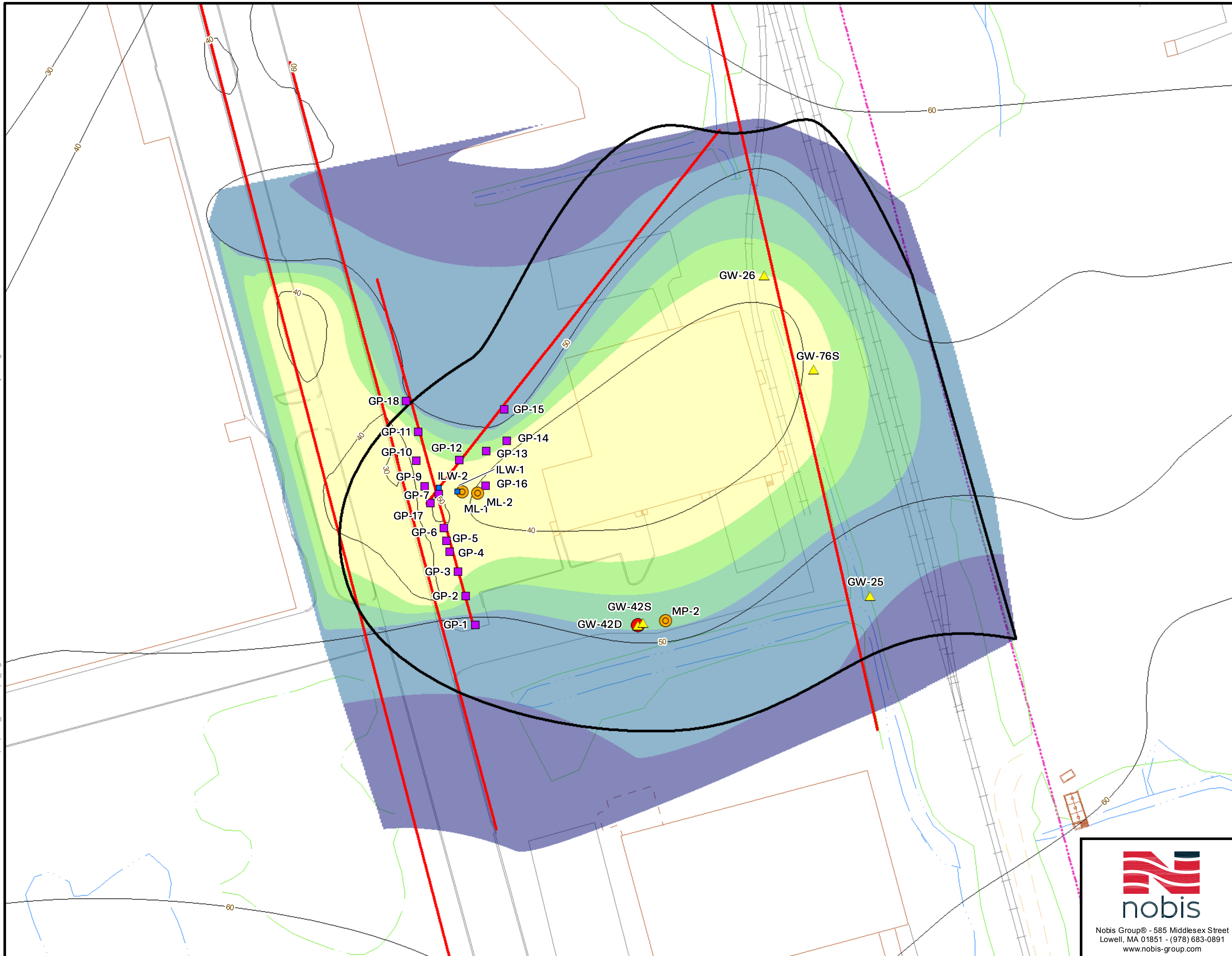

Notes:

1. Bedrock contours from Nobis, 2018. Technical Review Memorandum, Draft Remedial Investigation Report, Operable Unit 3. November 30.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Conventional Screened Well
- Bedrock Confirmation Location
- Multi-Port Well
- Induction Logging Well
- DPT Locations
- Geophysical Line
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 40 - 43
- 43 - 46
- 46 - 49
- 49 - 52
- 52 - 56

0 37.5 75 150

Feet

1 inch = 75 feet

N

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FIGURE 4B

NOBIS BEDROCK SURFACE
(NOBIS, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018

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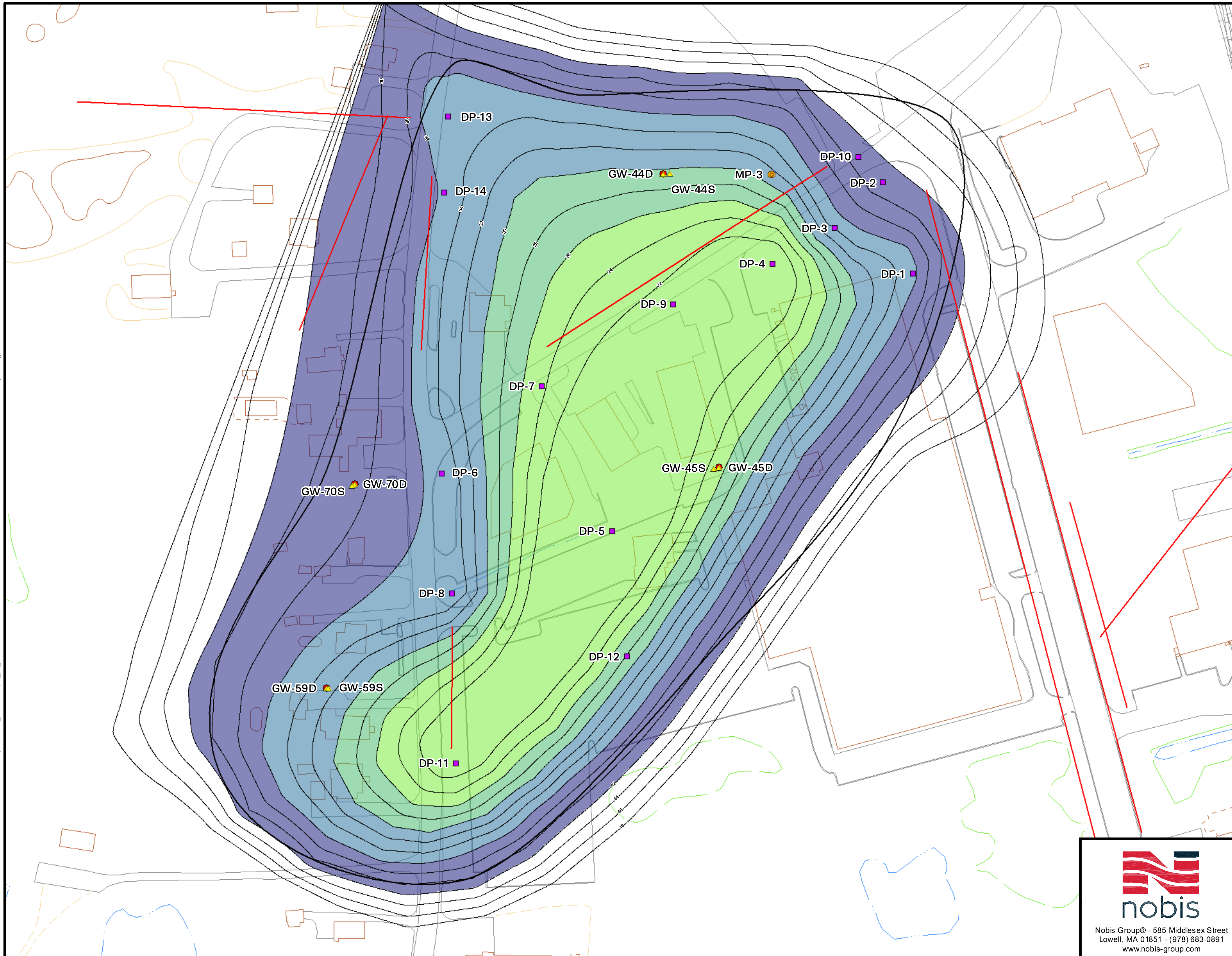

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Notes:

1. Bedrock contours AMEC, 2018. Draft Remedial Investigation Report, Operable Unit 3. Olin Chemical Superfund Site, Wilmington, Massachusetts. March 30.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Bedrock Confirmation Location
- Multi-Port Well
- Conventional Screened Well
- DPT Locations
- Geophysical Line
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 10 - 18
- 18 - 26
- 26 - 30
- 30 - 36
- 36 - 42

0 62.5 125 250

Feet

1 inch = 125 feet

N

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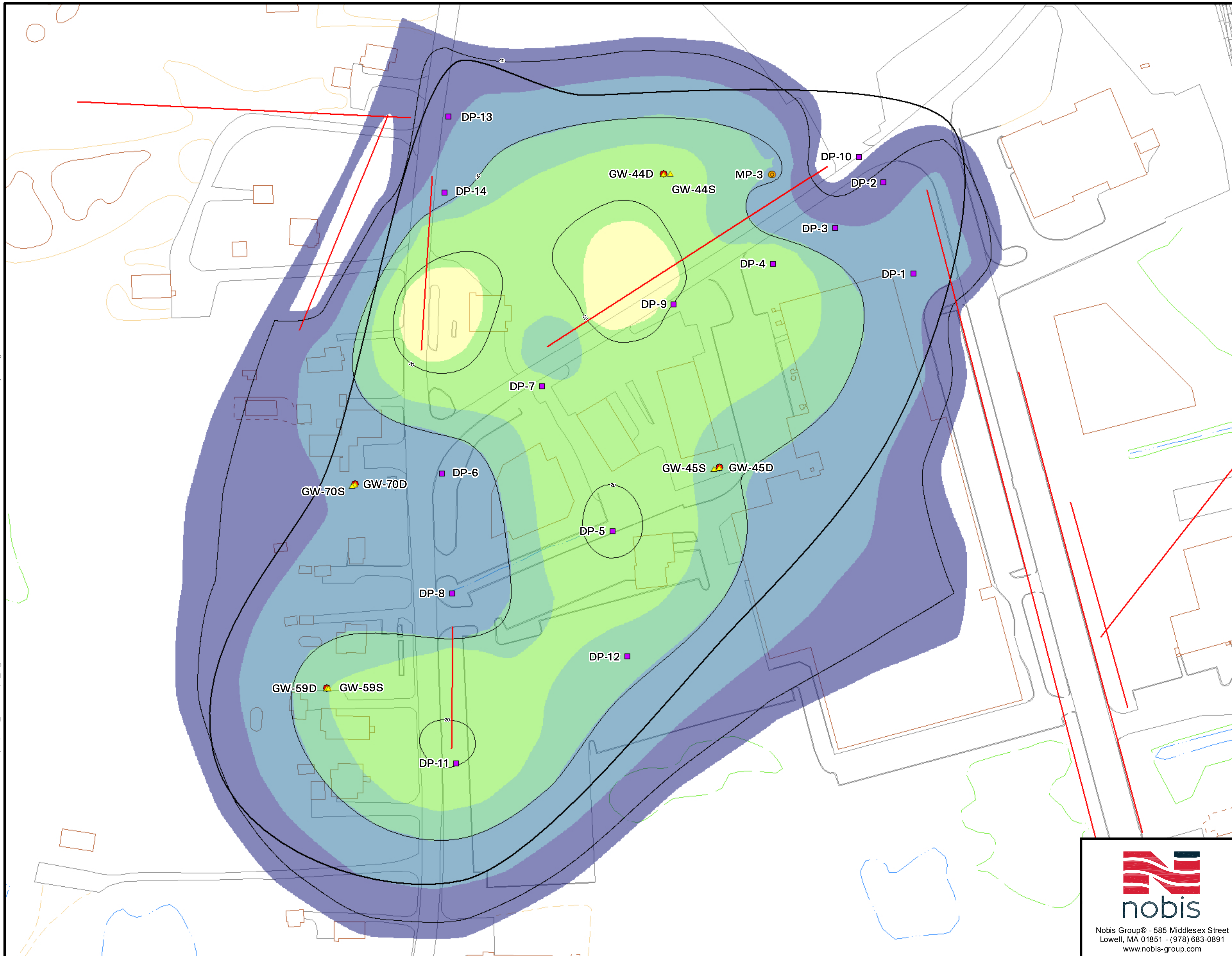
FIGURE 5A

AMEC RI BEDROCK SURFACE
(AMEC, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018



Notes:

1. Bedrock contours from Olin, 2018. Slides to support December 10, 2018 team meeting. Provided December 11.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Bedrock Confirmation Location
- Multi-Port Well
- Conventional Screened Well
- DPT Locations
- Geophysical Line
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 10 - 18
- 18 - 26
- 26 - 30
- 30 - 36
- 36 - 42

0 62.5 125 250

Feet

1 inch = 125 feet

N

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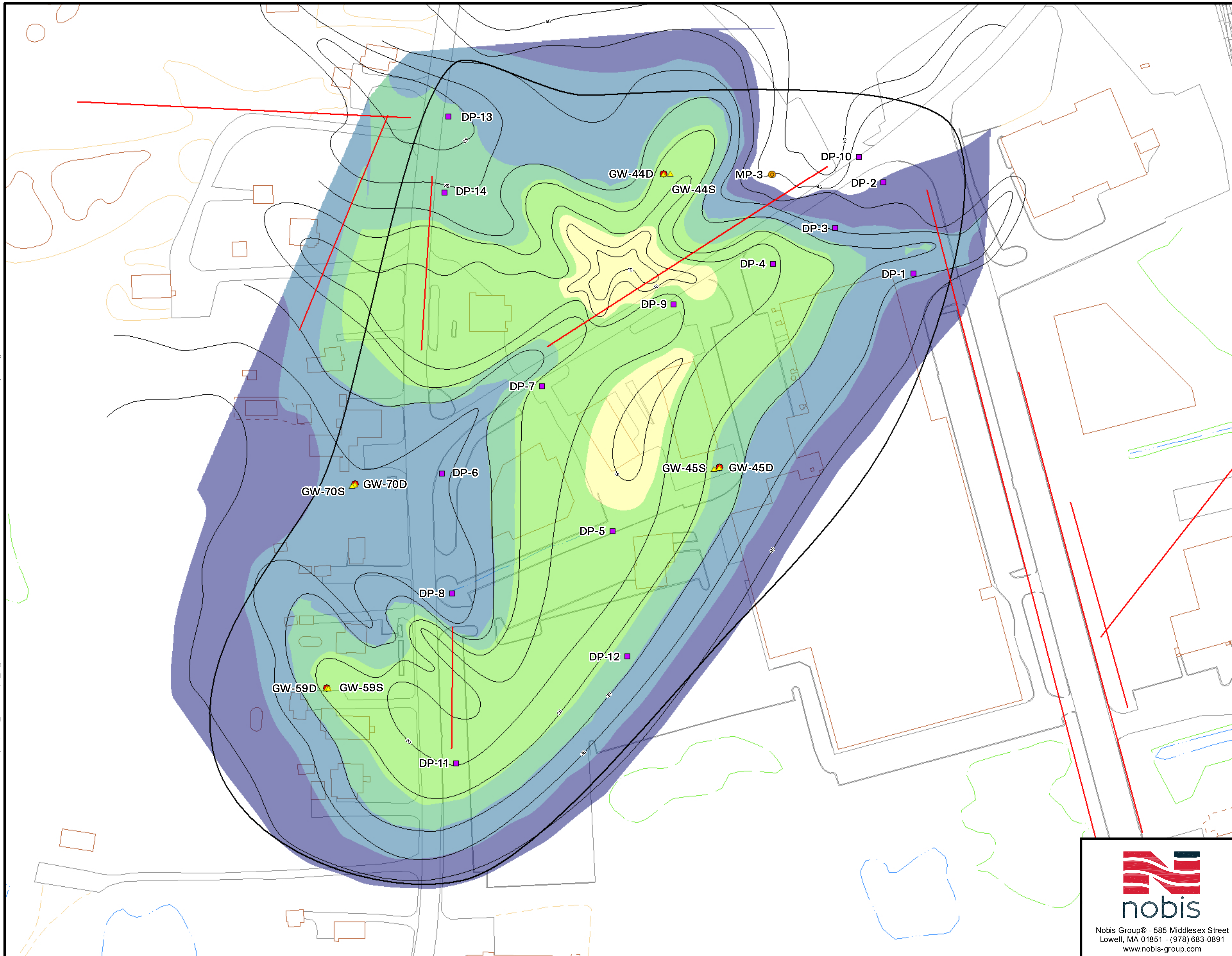
FIGURE 5B

AMEC/OLIN UPDATED BEDROCK SURFACE
(OLIN, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018

R:\80000 Task Orders\80021 Olin Chemical\Technical Data (TD)\GIS_Data\Maps_Figures\DAPL Volumes 2019\Olin DAPL Volumes 2019.mxd 6/24/2019 10:51 jharrington



Notes:

1. Bedrock contours from EPA, 2018. Slides to support December 10, 2018 team meeting. Provided December 11.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Bedrock Confirmation Location
- Multi-Port Well
- Conventional Screened Well
- DPT Locations
- Geophysical Line
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 10 - 18
- 18 - 26
- 26 - 30
- 30 - 36
- 36 - 42

0 62.5 125 250

Feet

1 inch = 125 feet

N

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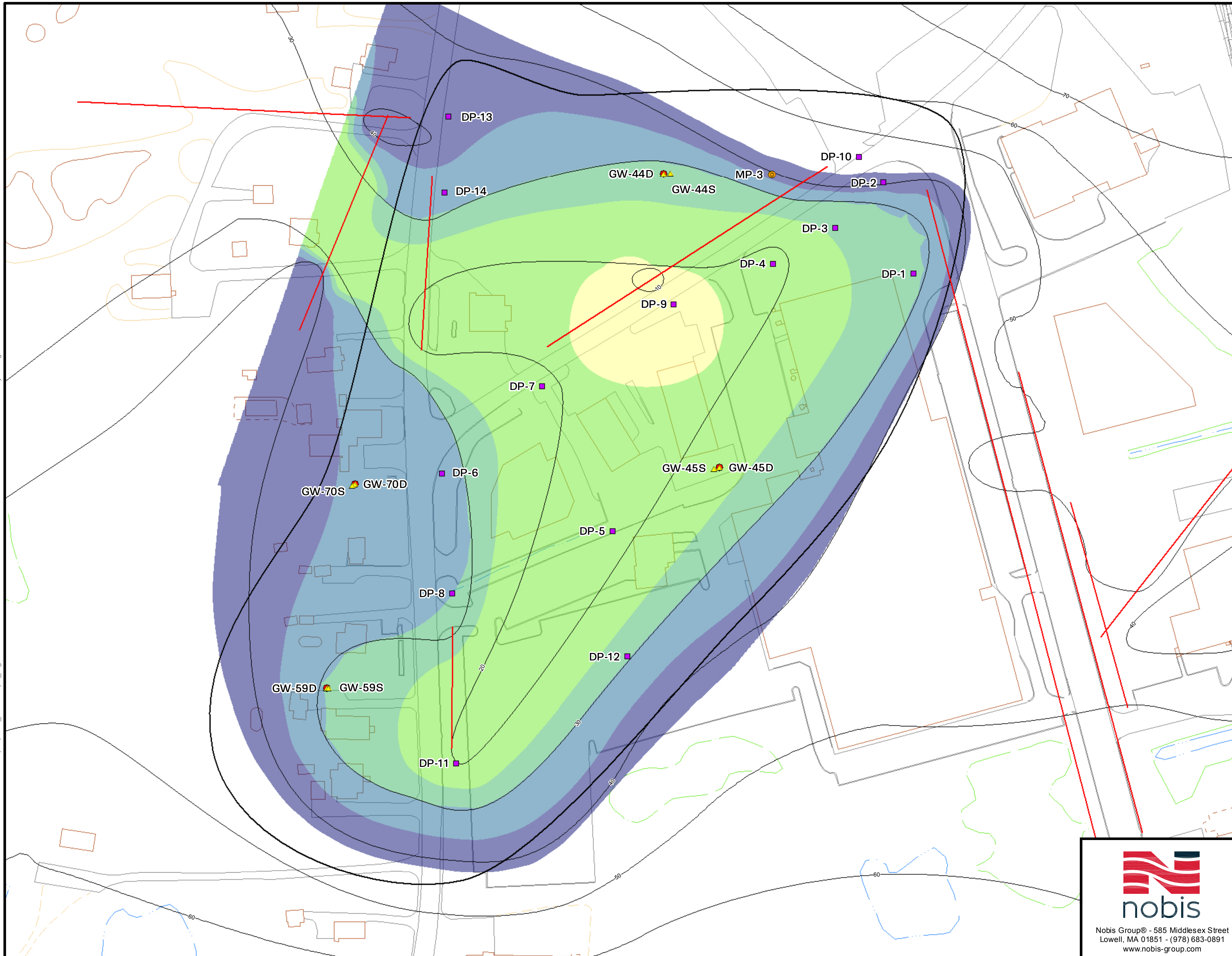
FIGURE 5C

EPA BEDROCK SURFACE
(EPA, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018



Notes:

1. Bedrock contours from Nobis, 2018. Technical Review Memorandum, Draft Remedial Investigation Report, Operable Unit 3. November 30.

2. This Site Sketch was developed from elevation data from Mactec, Amec Foster Wheeler, Wood, and observations made by Nobis.

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

- Bedrock Confirmation Location
- Multi-Port Well
- Conventional Screened Well
- DPT Locations
- Geophysical Line
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

DAPL Area BR Elevation

- 10 - 18
- 18 - 26
- 26 - 30
- 30 - 36
- 36 - 42

0 62.5 125 250
Feet
1 inch = 125 feet
N

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FIGURE 5D

NOBIS BEDROCK SURFACE
(NOBIS, 2018)
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2018

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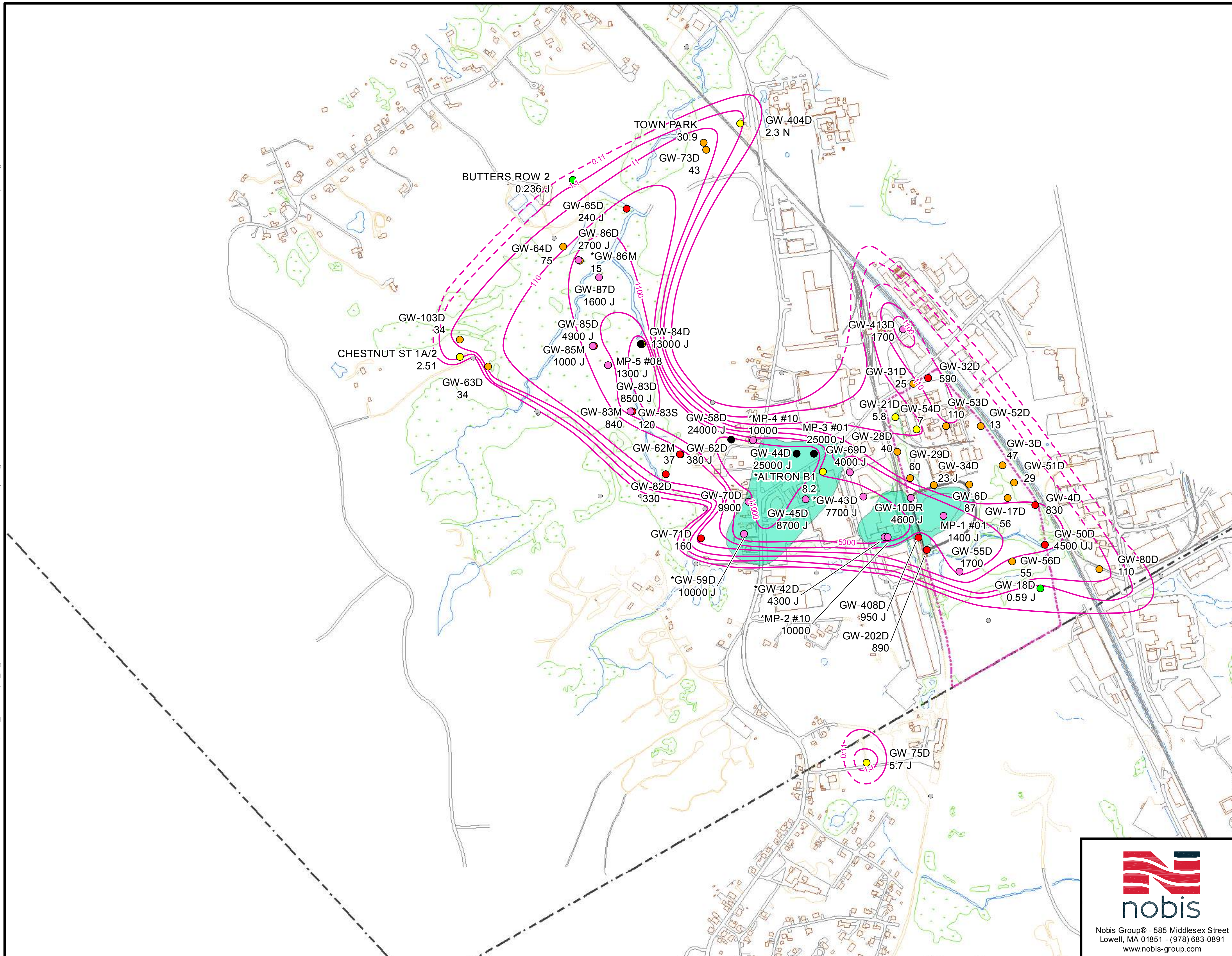

Notes:

1. Maximum result from 2010-2017 sampling events is labeled. If data are not available from 2010-2017, the most recent detection from 2003-2017 is included and labeled with an asterisk

2. All concentrations shown are in nanograms per liter (ng/L).

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

NDMA in Deep Overburden
Tapwater RSL = 0.11 ng/L

- < Reporting Limit
- 0.11 - 1.1
- 1.1 - 11
- 11 - 110
- 110 - 1,100
- 1,100 - 11,000
- 11,000 - 110,000
- NDMA Isocencentration Contour
- Inferred NDMA Contour
- DAPL Pools
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

N

0 400 800 1,600
Feet
1 inch = 800 feet

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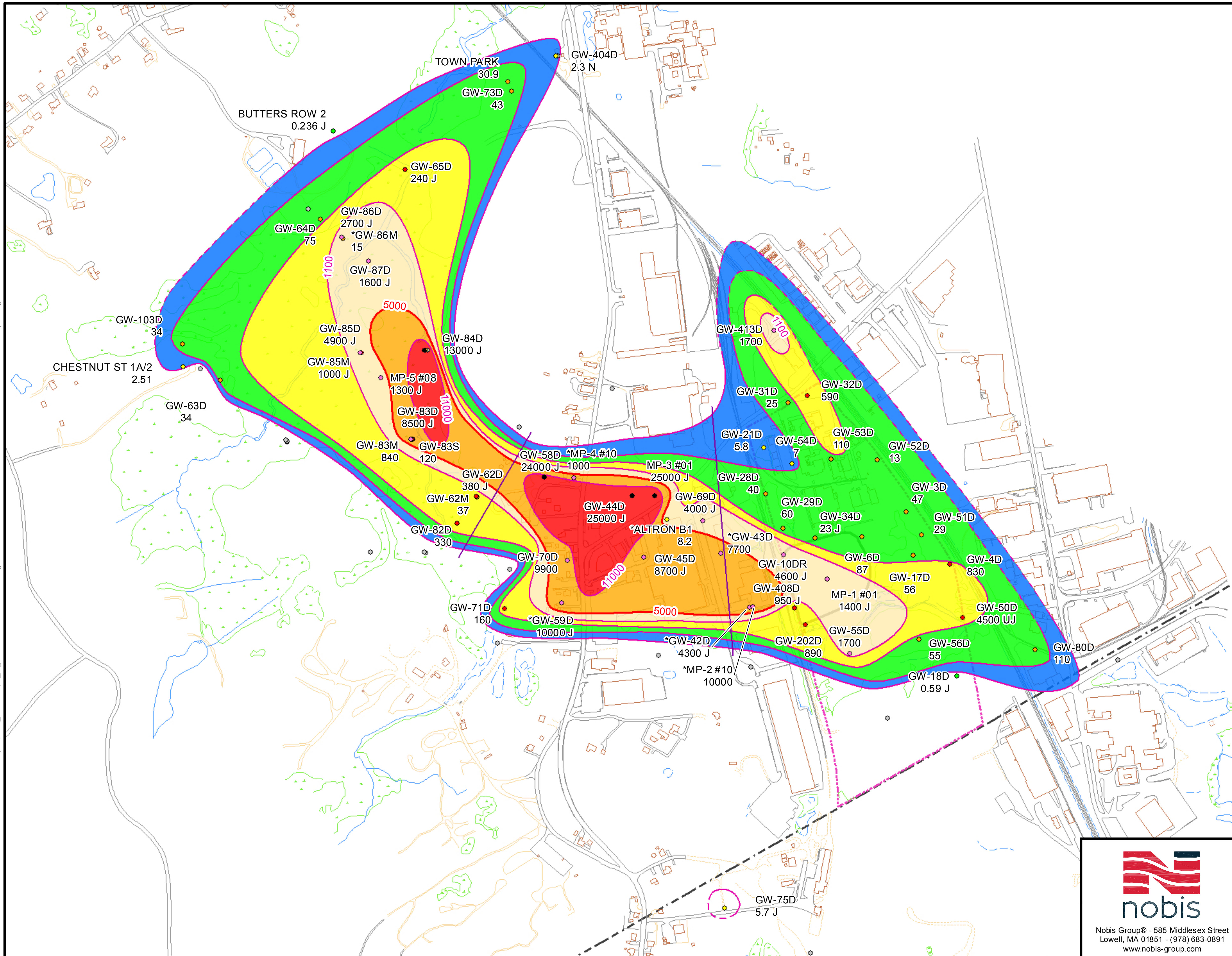
FIGURE 6

NDMA IN DEEP
OVERBURDEN GROUNDWATER
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JULY 2019

R:\80000 Task Orders\80021 Olin Chemical\Technical Data (TD)\GIS_Data\Maps_Figures\2018 Groundwater\Contaminant Contour Maps\Figure 1 thru 9 Olin 2018 GW Contaminant Contours.mxd 7/18/2019 08:31 jharrington



Notes:

1. Maximum result from 2010-2017 sampling events is labeled. If data are not available from 2010-2017, the most recent detection from 2003-2017 is included and labeled with an asterisk.

2. All concentrations shown are in nanograms per liter (ng/L).

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

NDMA in Deep Overburden

Tapwater RSL = 0.11 ng/L

- < Reporting Limit
- 0.11 - 1.1
- 1.1 - 11
- 11 - 110
- 110 - 1,100
- 1,100 - 11,000
- 11,000 - 110,000
- NDMA Isococentration Contour
- Inferred NDMA Contour
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

N

0 300 600 1,200

Feet

1 inch = 600 feet

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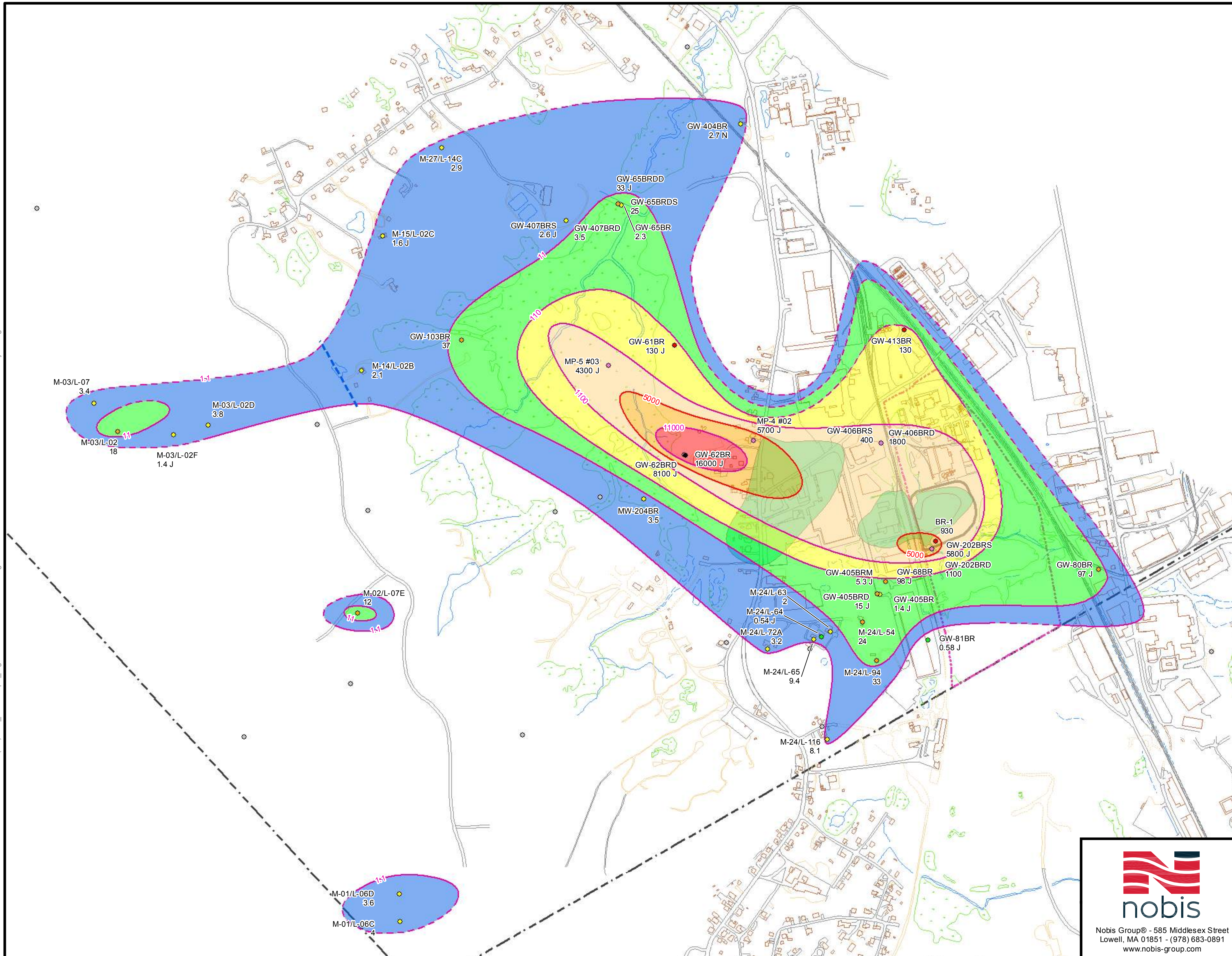
FIGURE 7A

NDMA IN DEEP
OVERBURDEN GROUNDWATER
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JULY 2019



Notes:

1. Maximum result from 2010-2017 sampling events is labeled.

2. All concentrations shown are in nanograms per liter (ng/L).

3. Locations of site features depicted hereon are approximate and given for illustrative purposes only.

Legend

NDMA in Bedrock
Tapwater RSL = 0.11 ng/L

- < Reporting Limit
- 0.11 - 1.1
- 1.1 - 11
- 11 - 110
- 110 - 1,100
- 1,100 - 11,000
- 11,000 - 110,000
- NDMA Isocoencentration Contour
- Inferred NDMA Contour
- Sub-Area Separation Line
- DAPL Pools
- Paved Road
- Unpaved Road
- Rail
- Site Boundary
- Water Features
- Buildings
- Wetlands

N

0 400 800 1,600
Feet
1 inch = 800 feet

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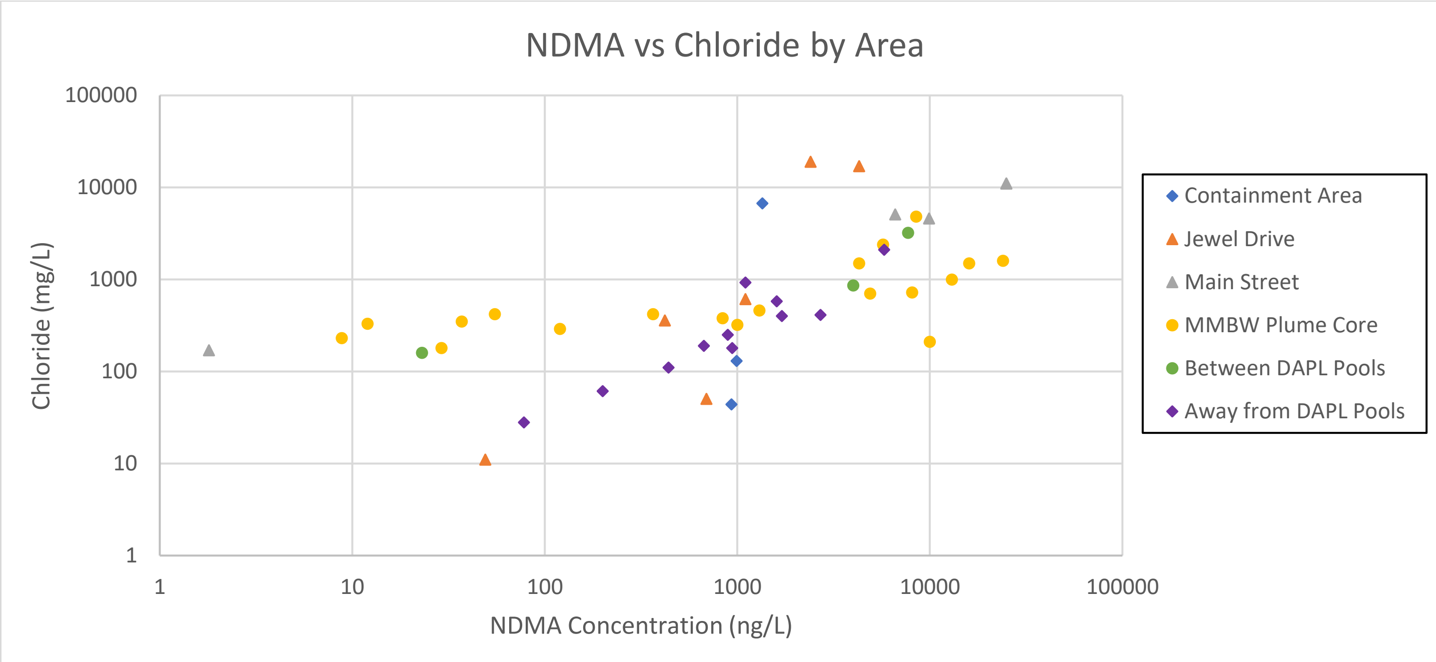
FIGURE 7B

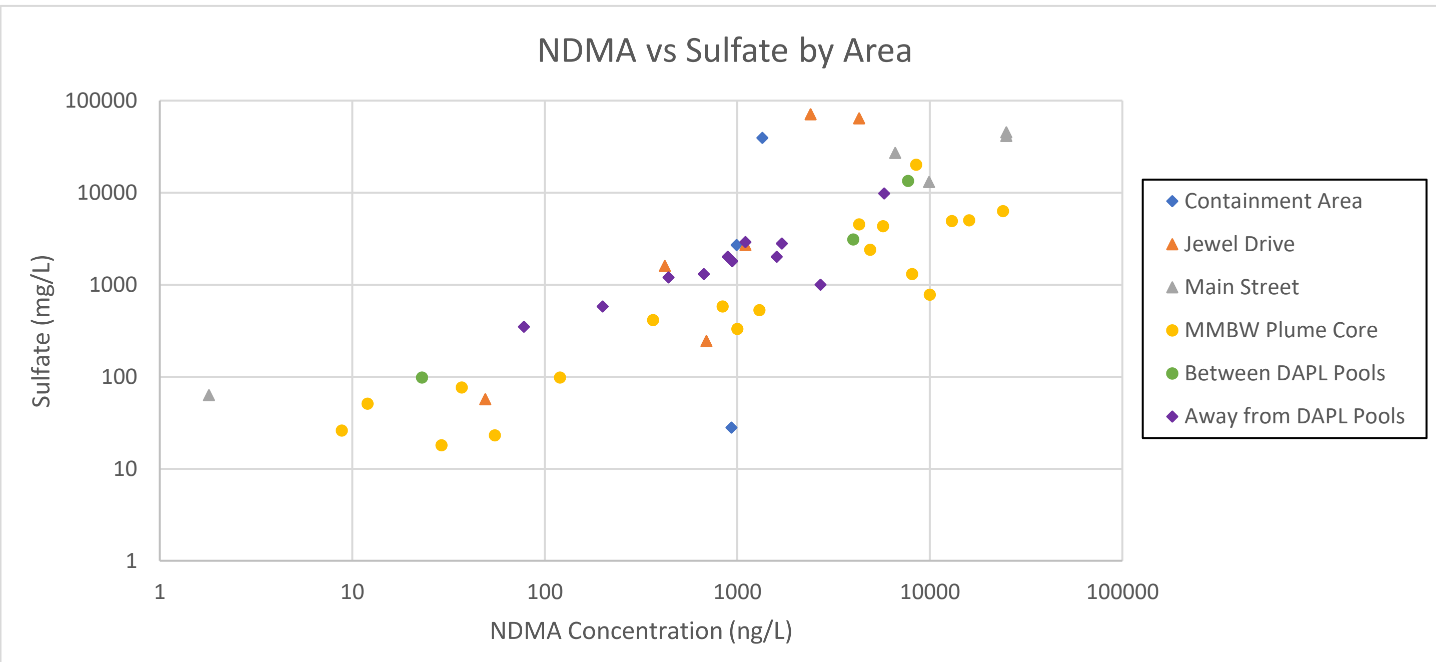
BEDROCK AREAS FOR
NDMA MASS CALCULATION
OLIN CHEMICAL SUPERFUND SITE
WILMINGTON, MASSACHUSETTS

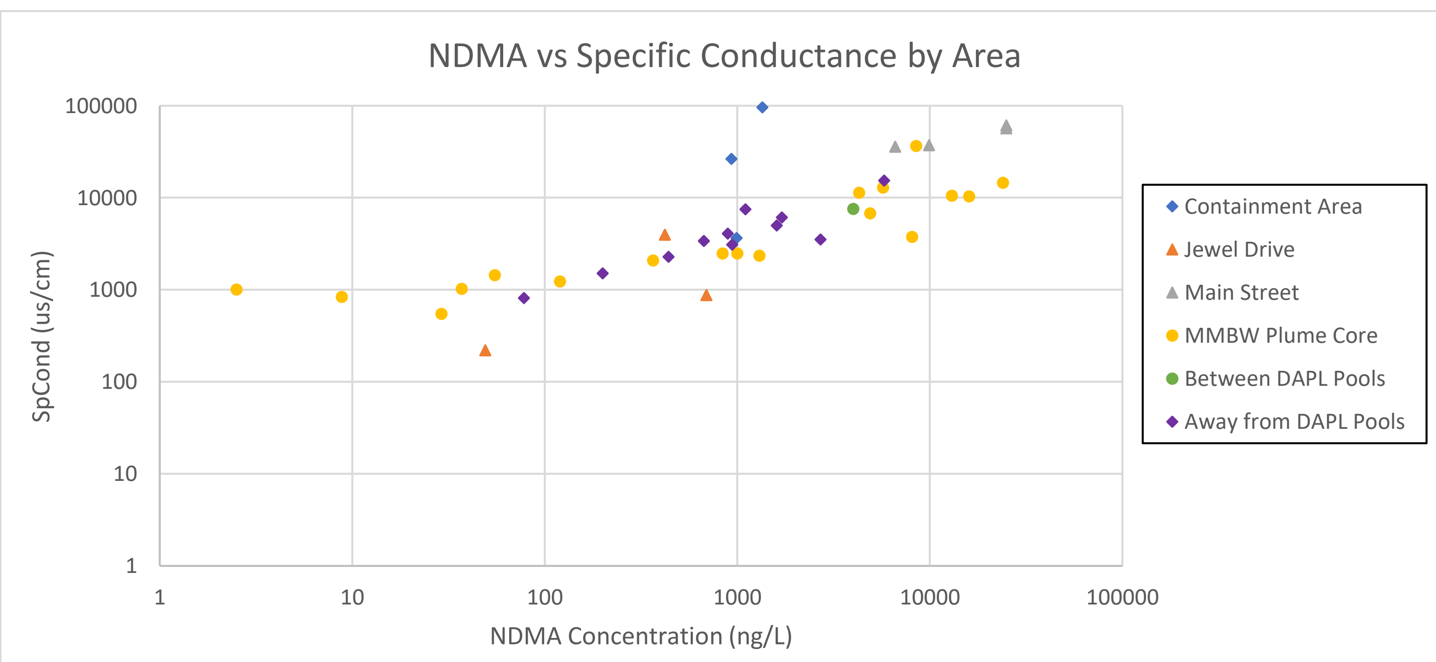
PREPARED BY: JH	CHECKED BY: JL
PROJECT NO. 80021	DATE: JUNE 2019

R:\80000 Task Orders\80021 Olin Chemical\Technical Data (TD)\GIS_Data\Maps_Figures\2018 Groundwater\Figure 7 Olin NDMA Volume Mass.mxd 6/24/2019 08:14 jharrington

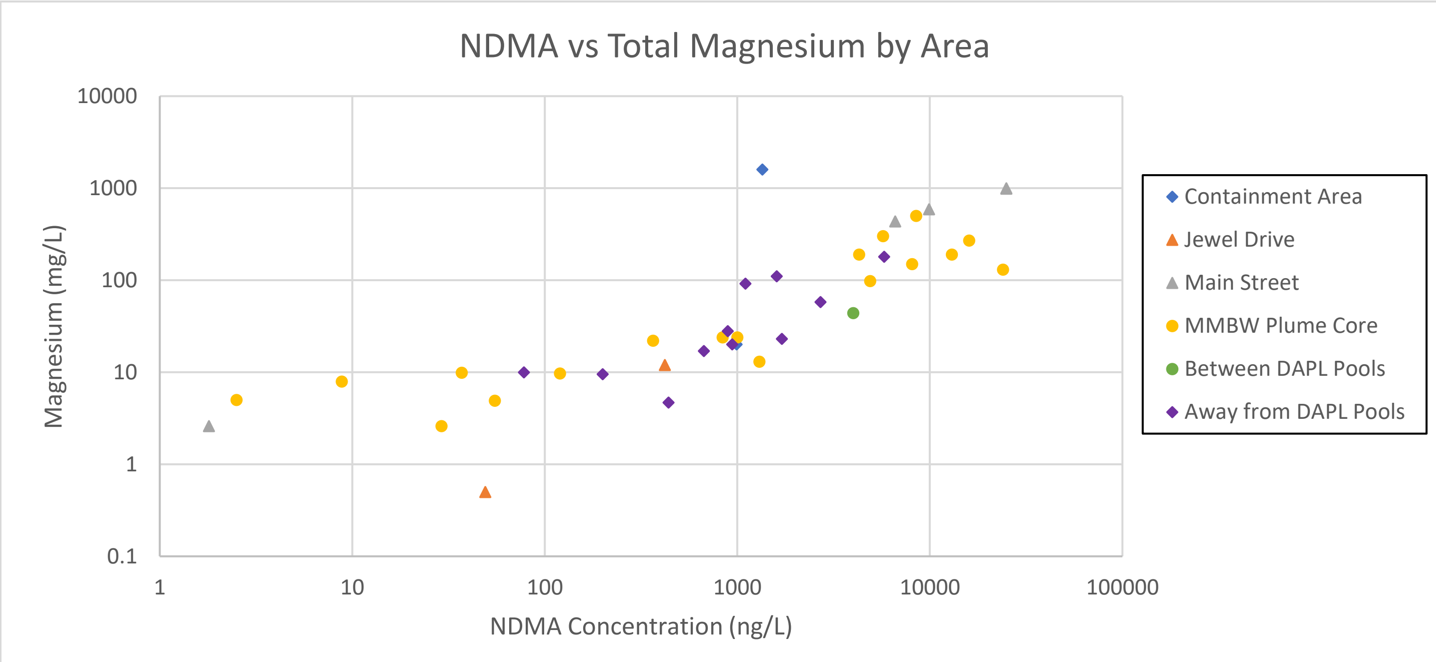
Attachment A: DAPL Indicator-NDMA Comparison
Olin Chemical Superfund Site
Wilmington, Massachusetts

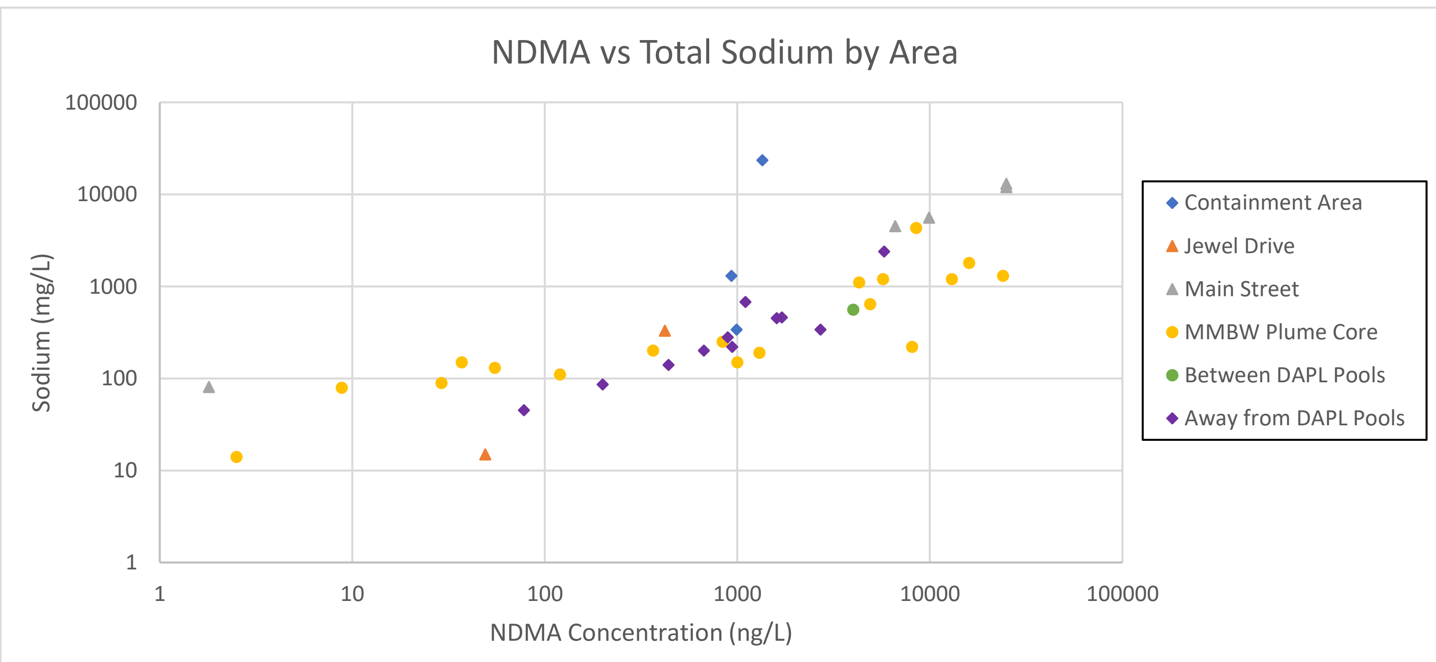




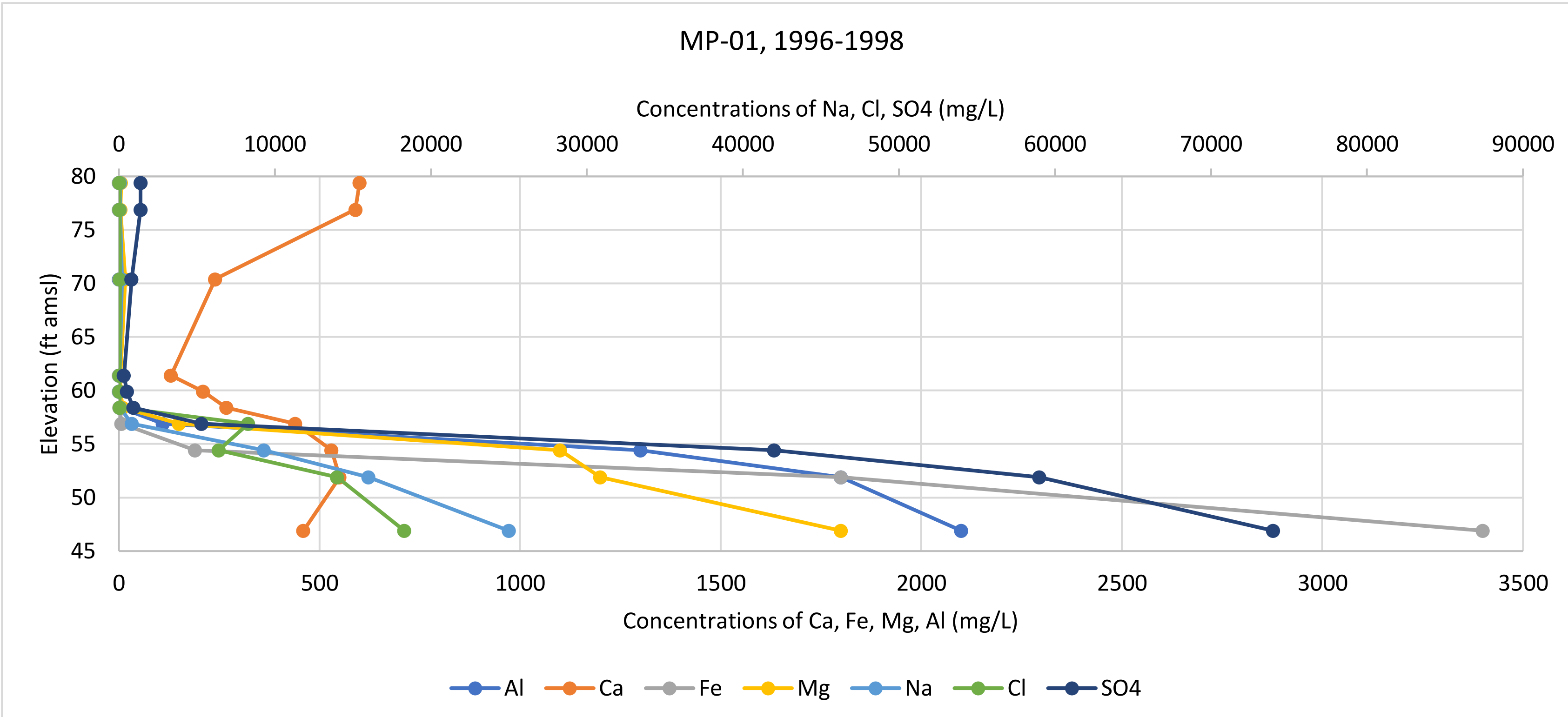


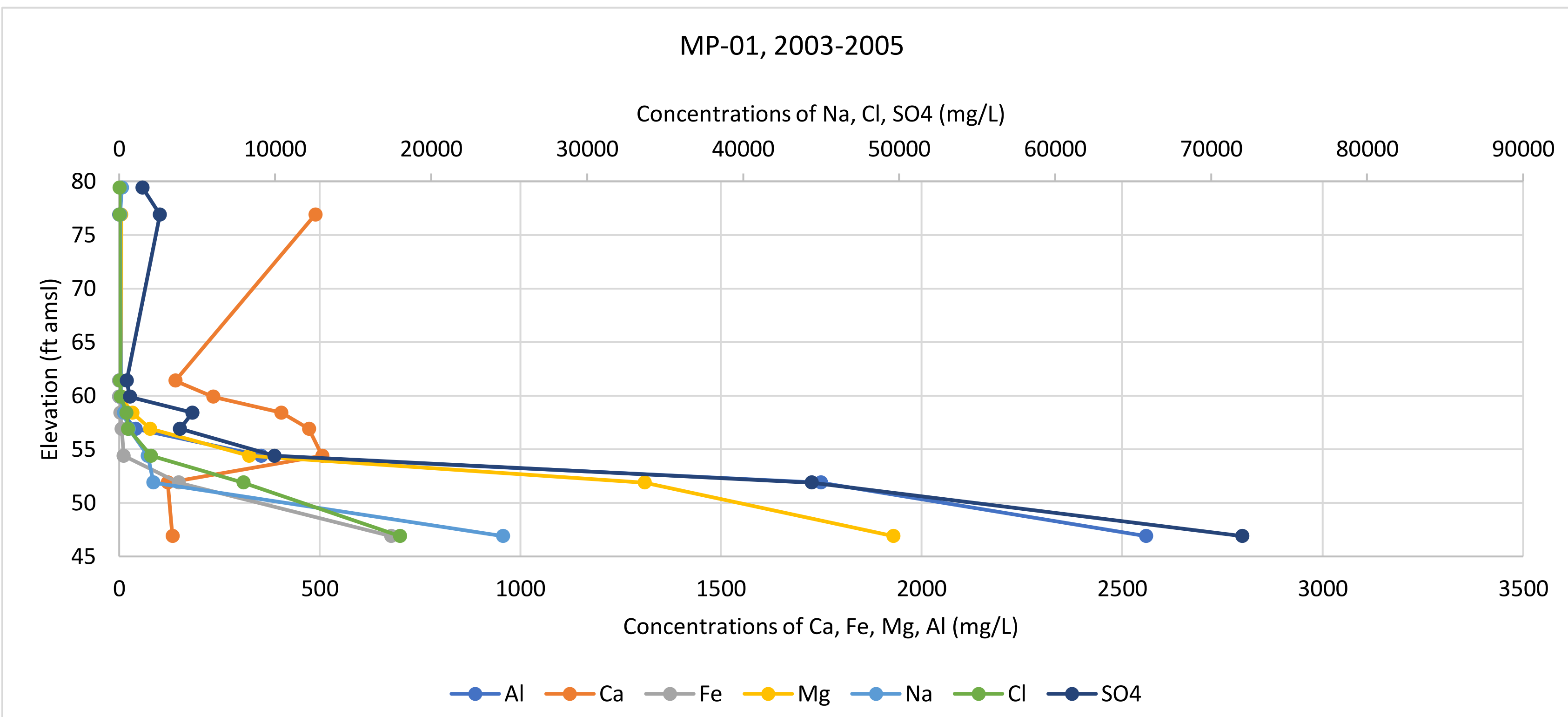
Attachment A: DAPL Indicator-NDMA Comparison
Olin Chemical Superfund Site
Wilmington, Massachusetts

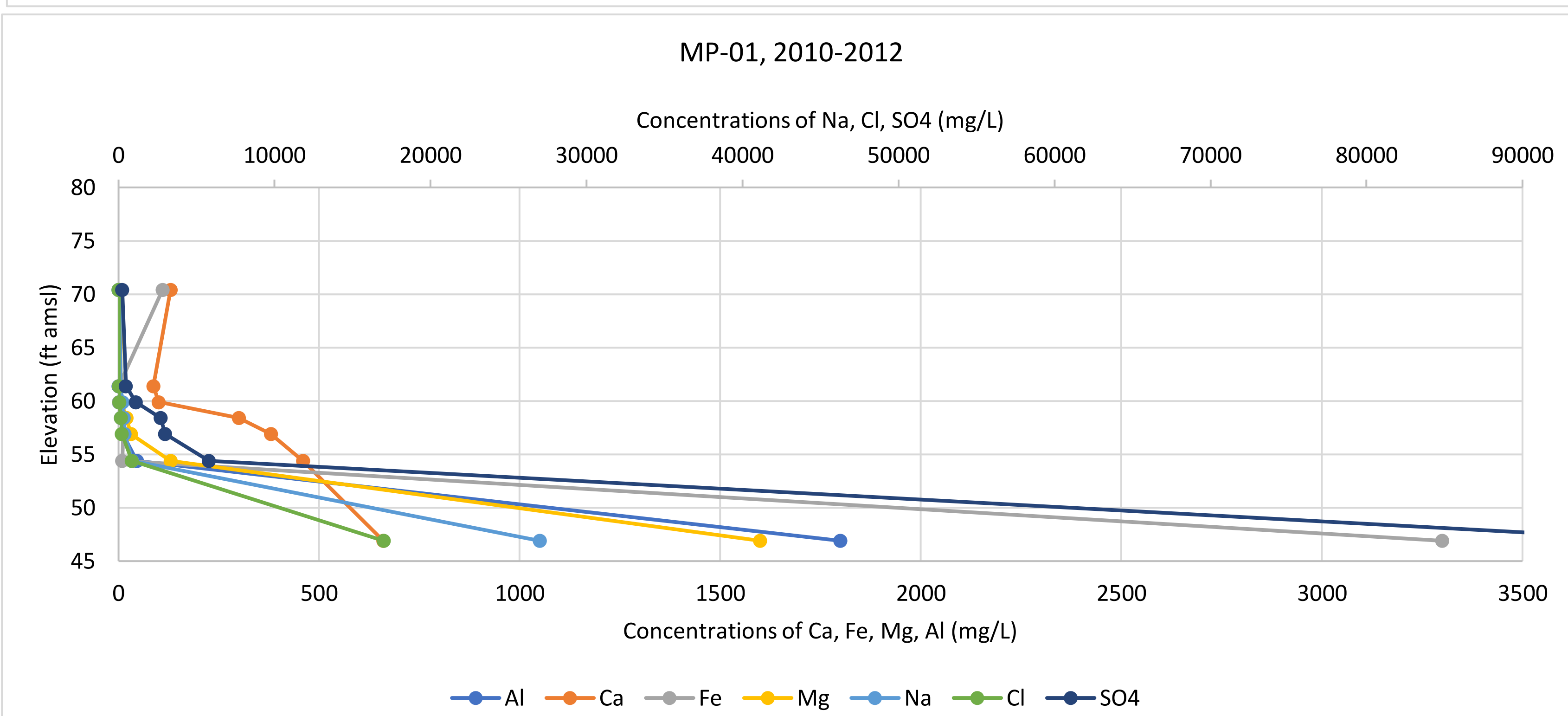




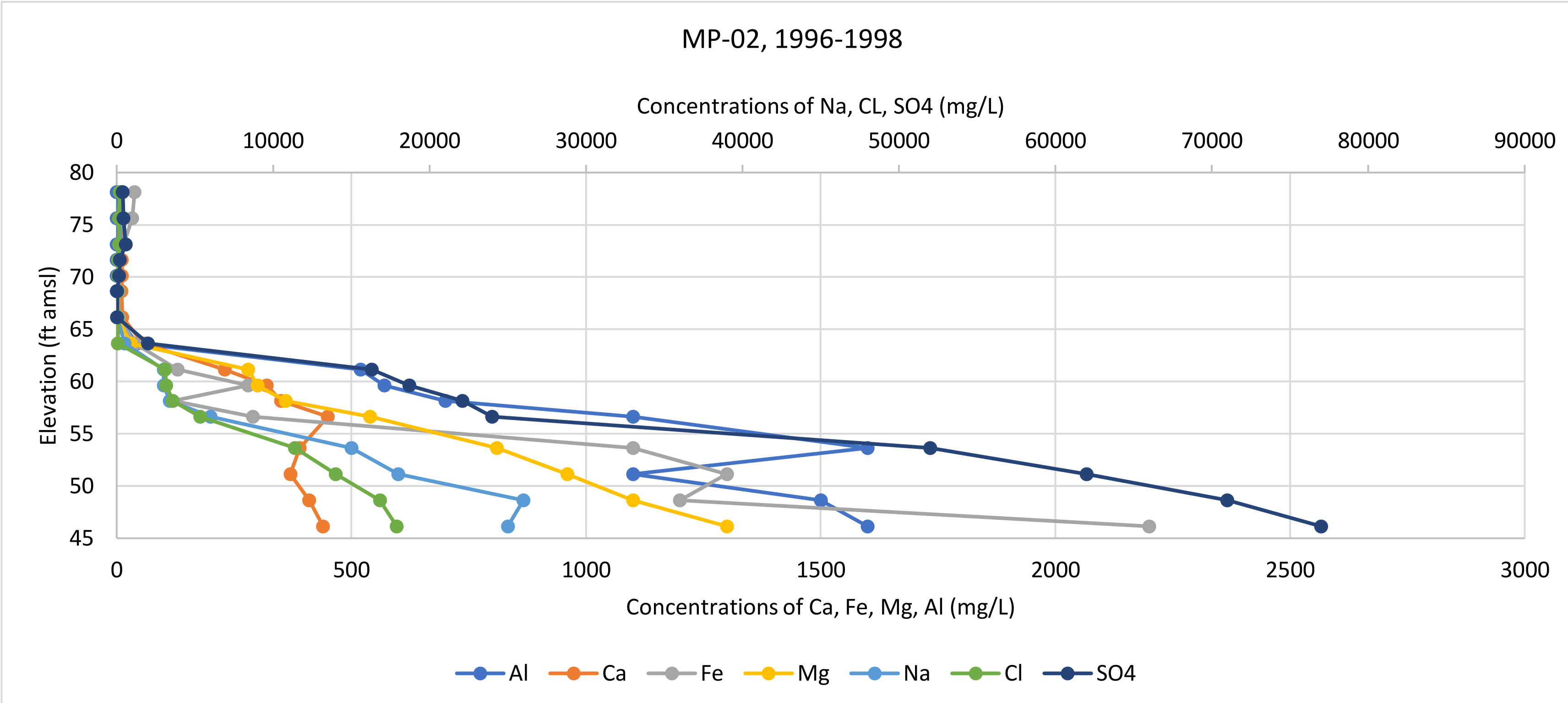
Attachment B
MP-01 Vertical Profiles
Olin Chemical Superfund Site
Wilmington, Massachusetts

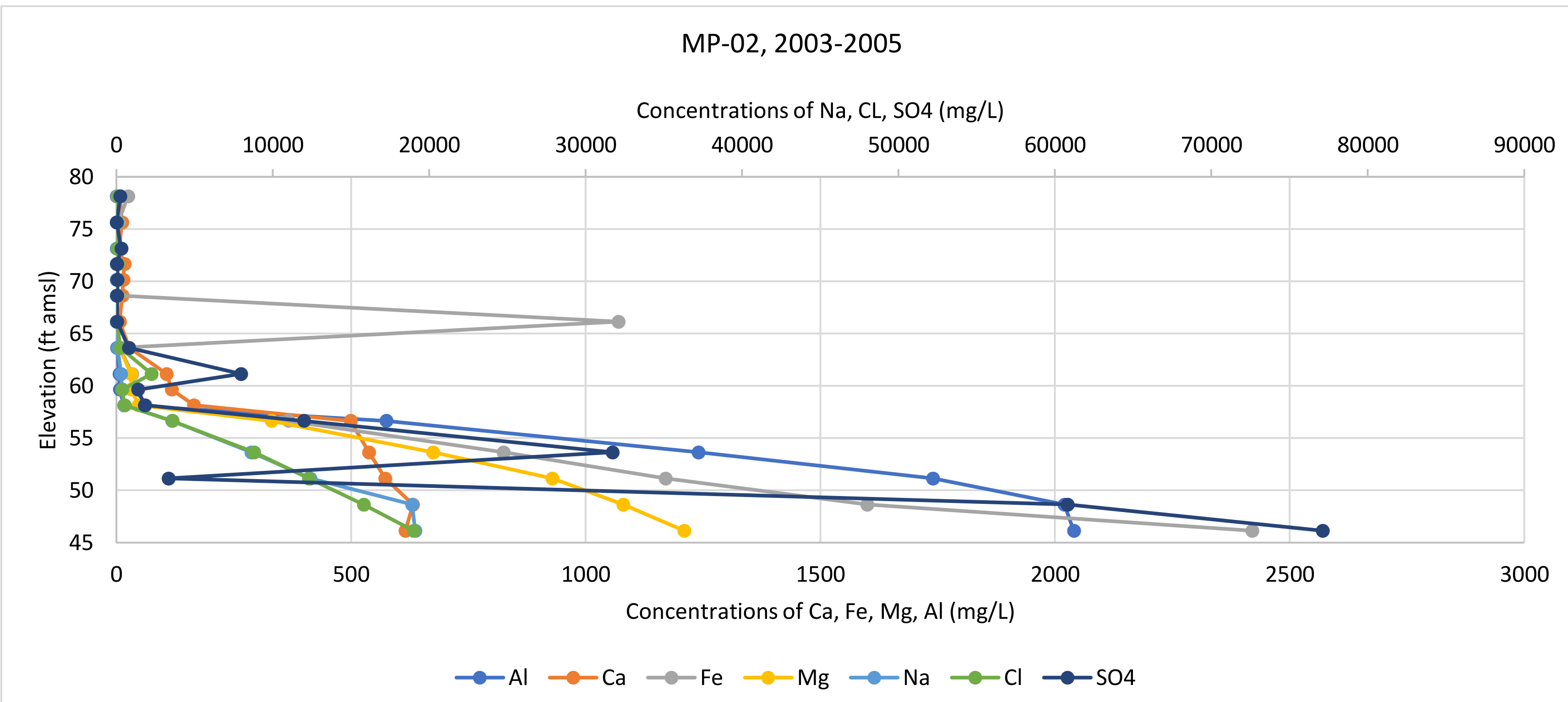


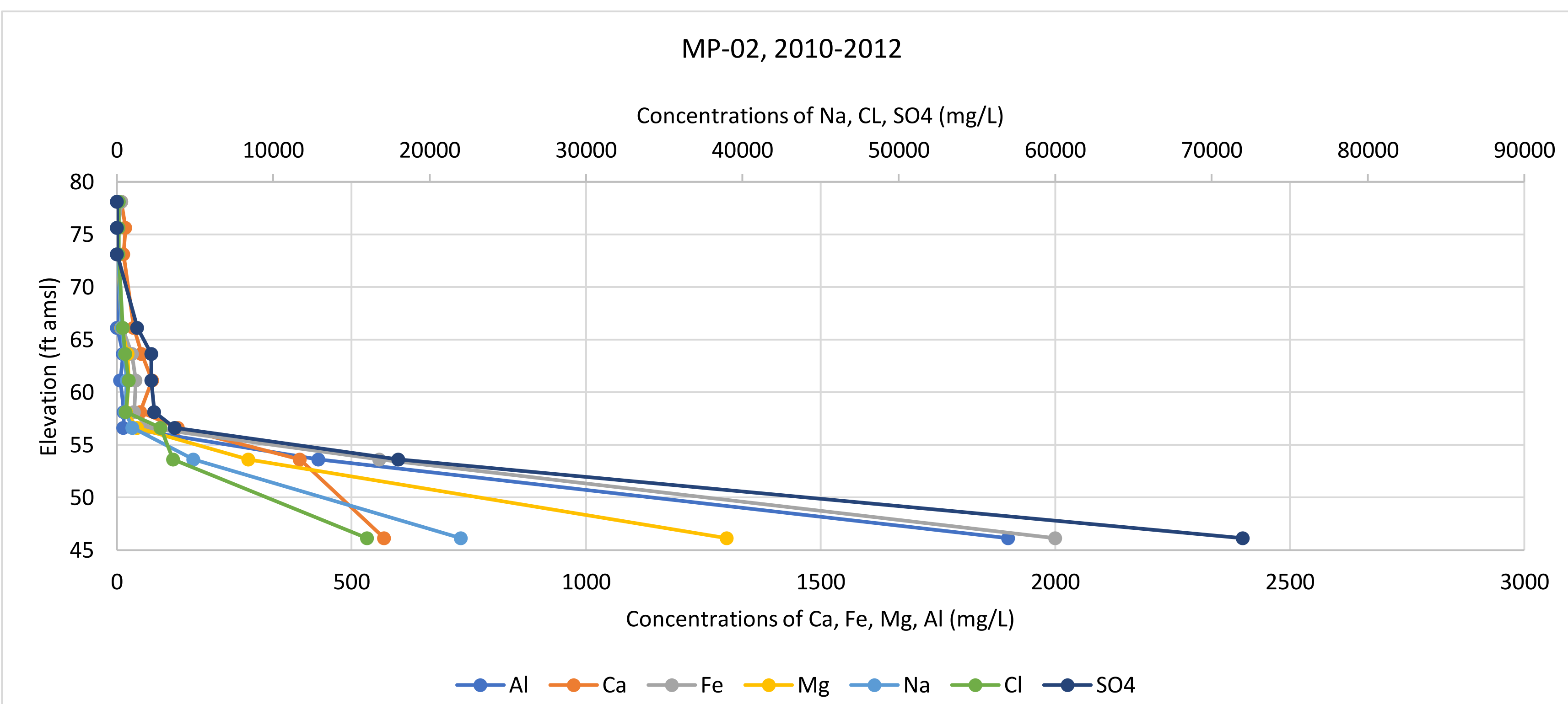




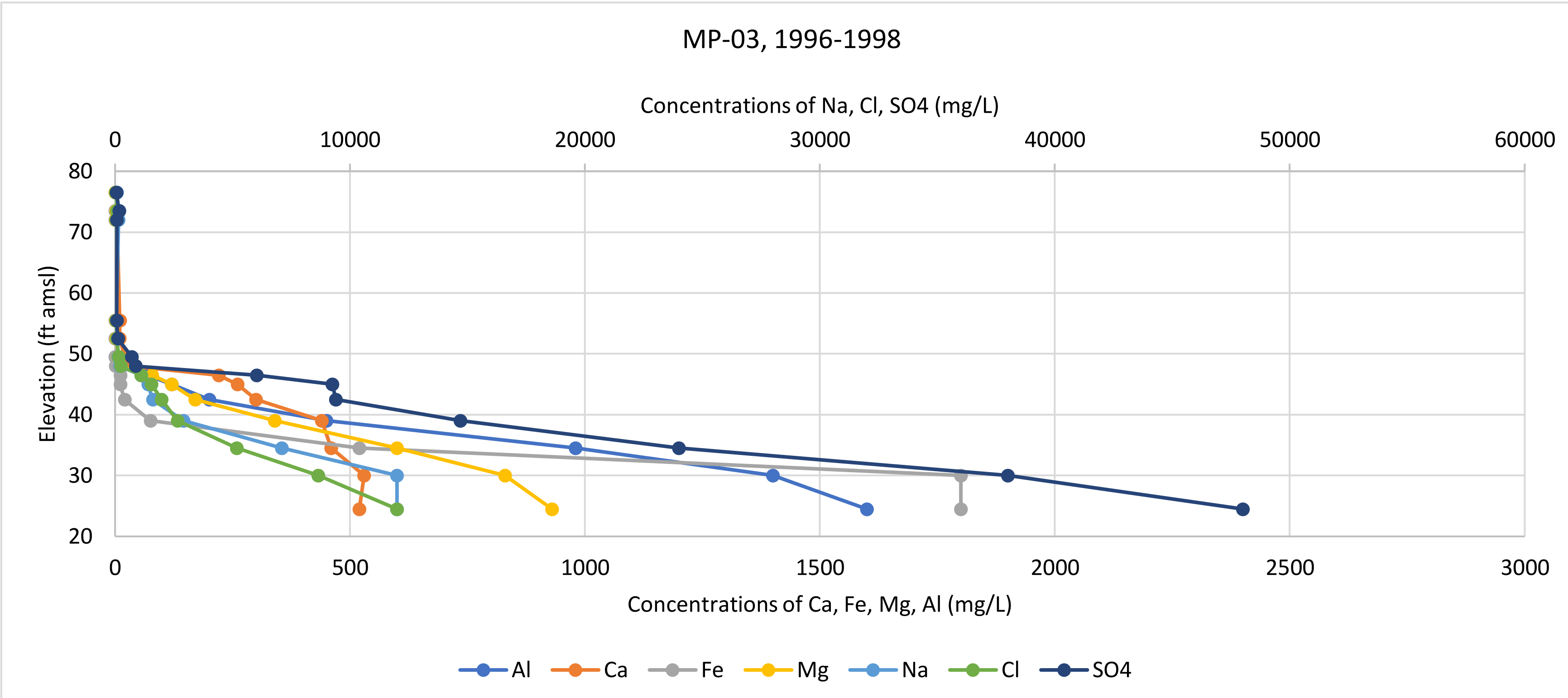
Attachment B
MP-02 Vertical Profiles
Olin Chemical Superfund Site
Wilmington, Massachusetts

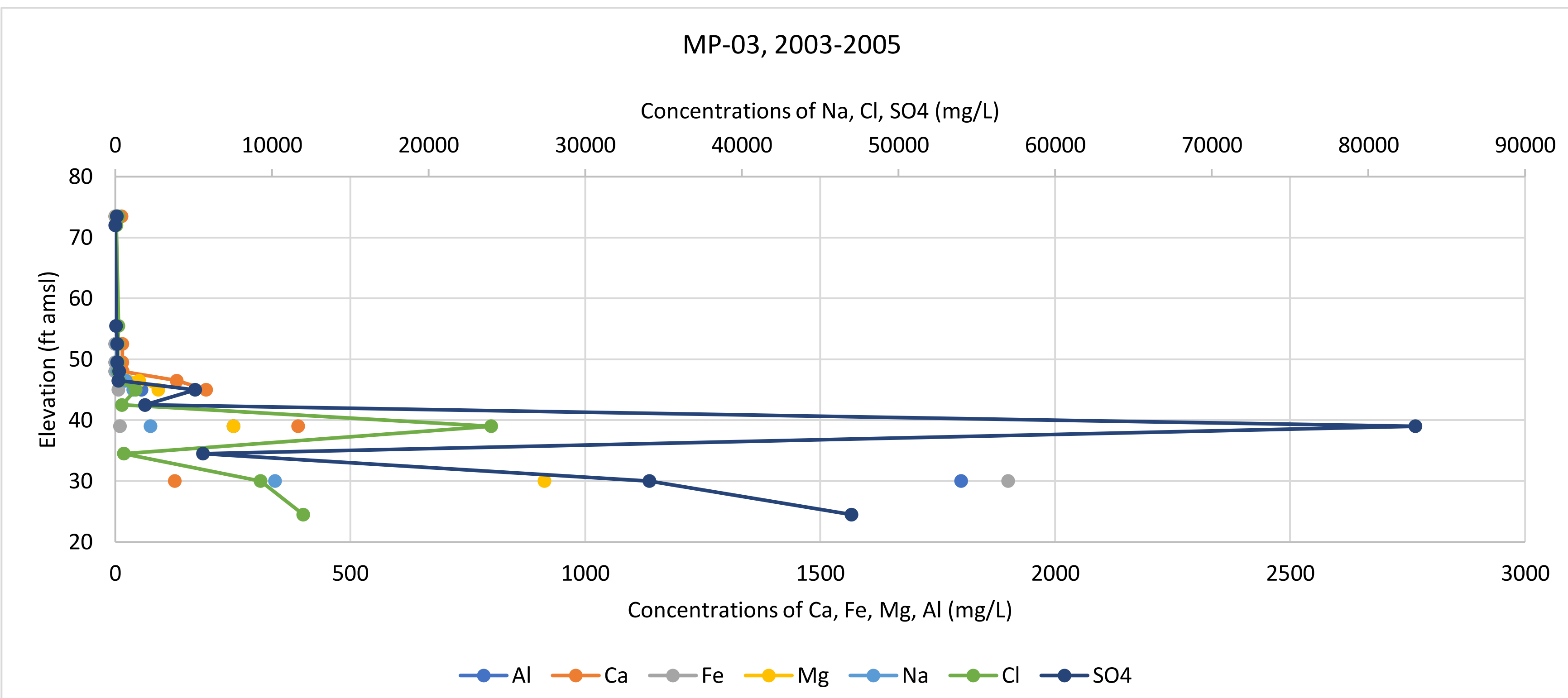


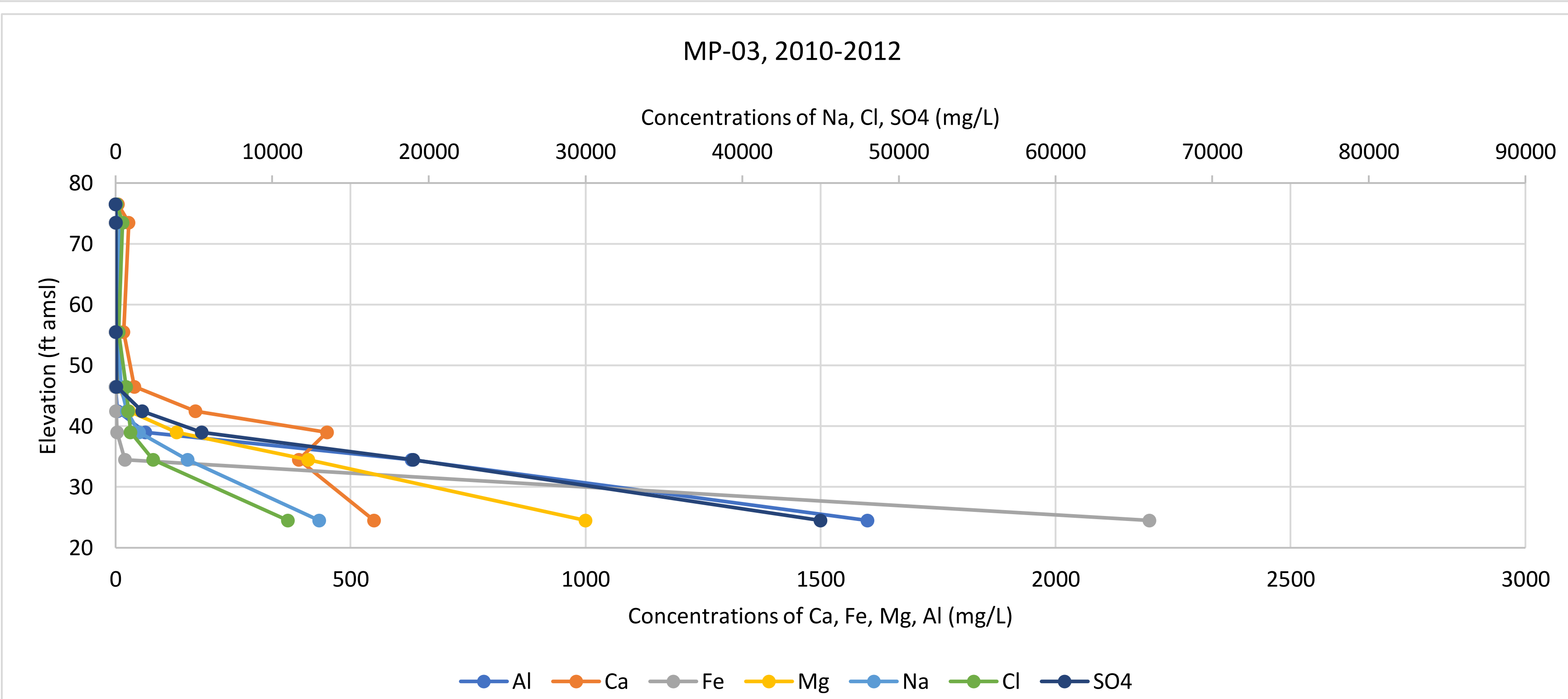




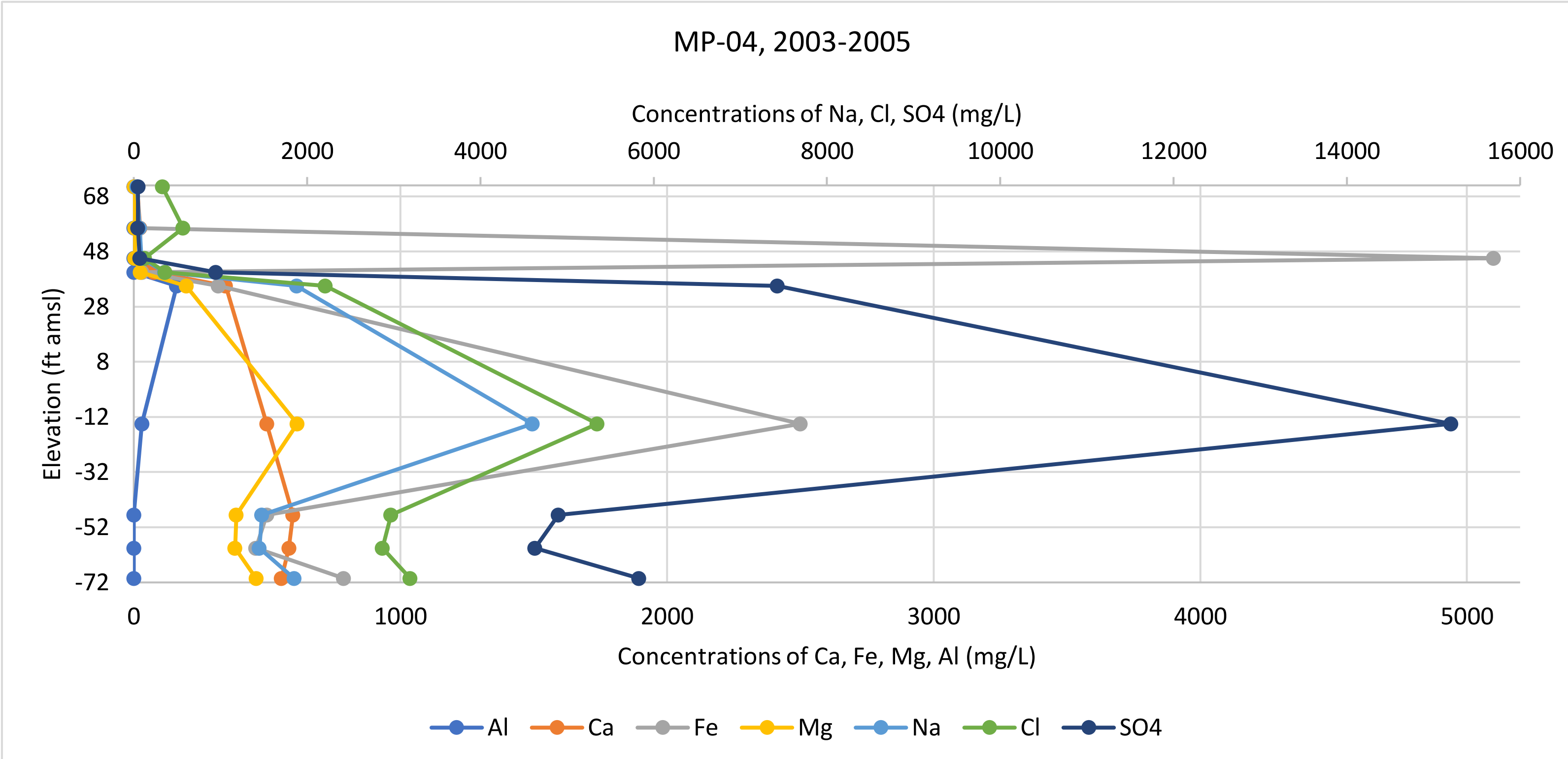
Attachment B
MP-03 Vertical Profiles
Olin Chemical Superfund Site
Wilmington, Massachusetts

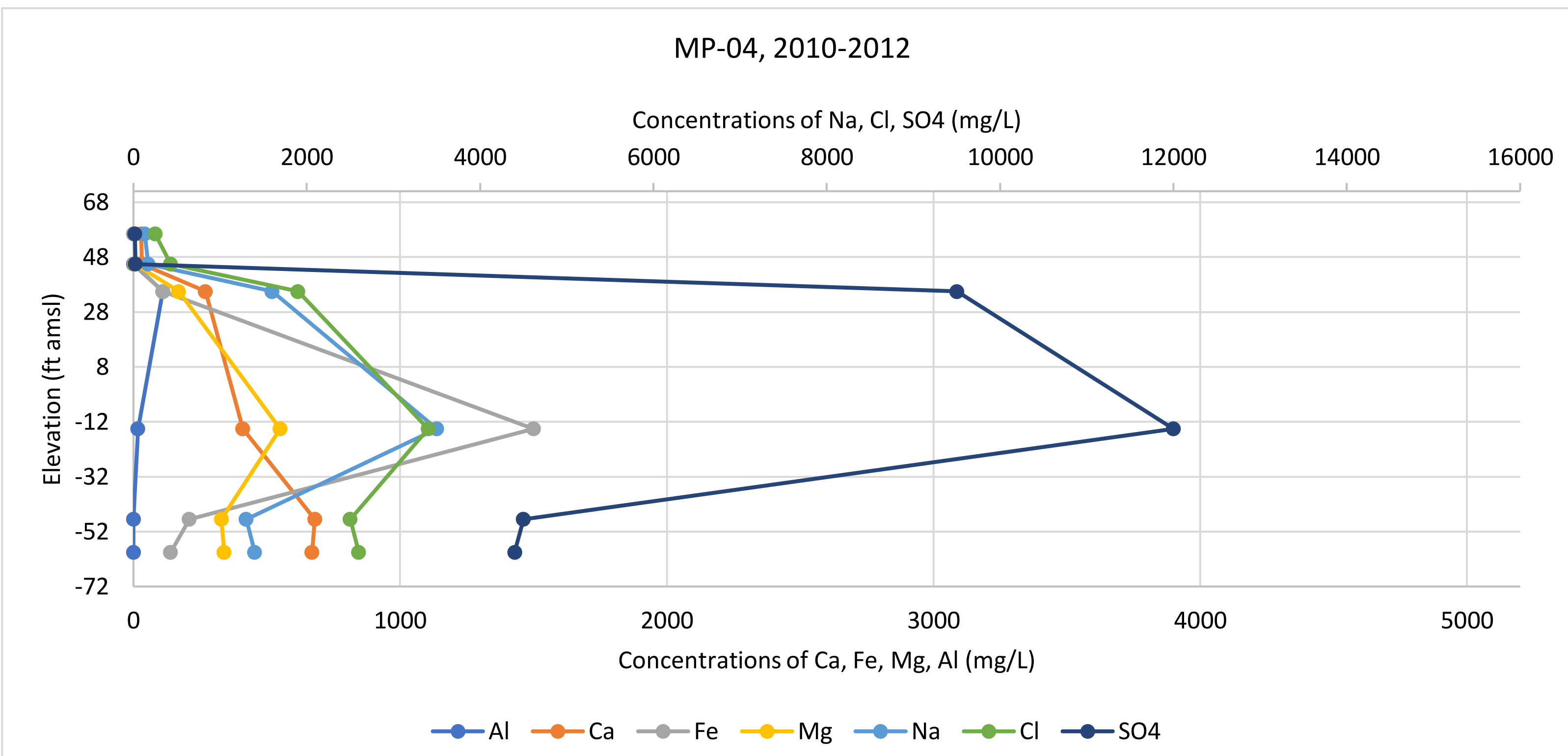




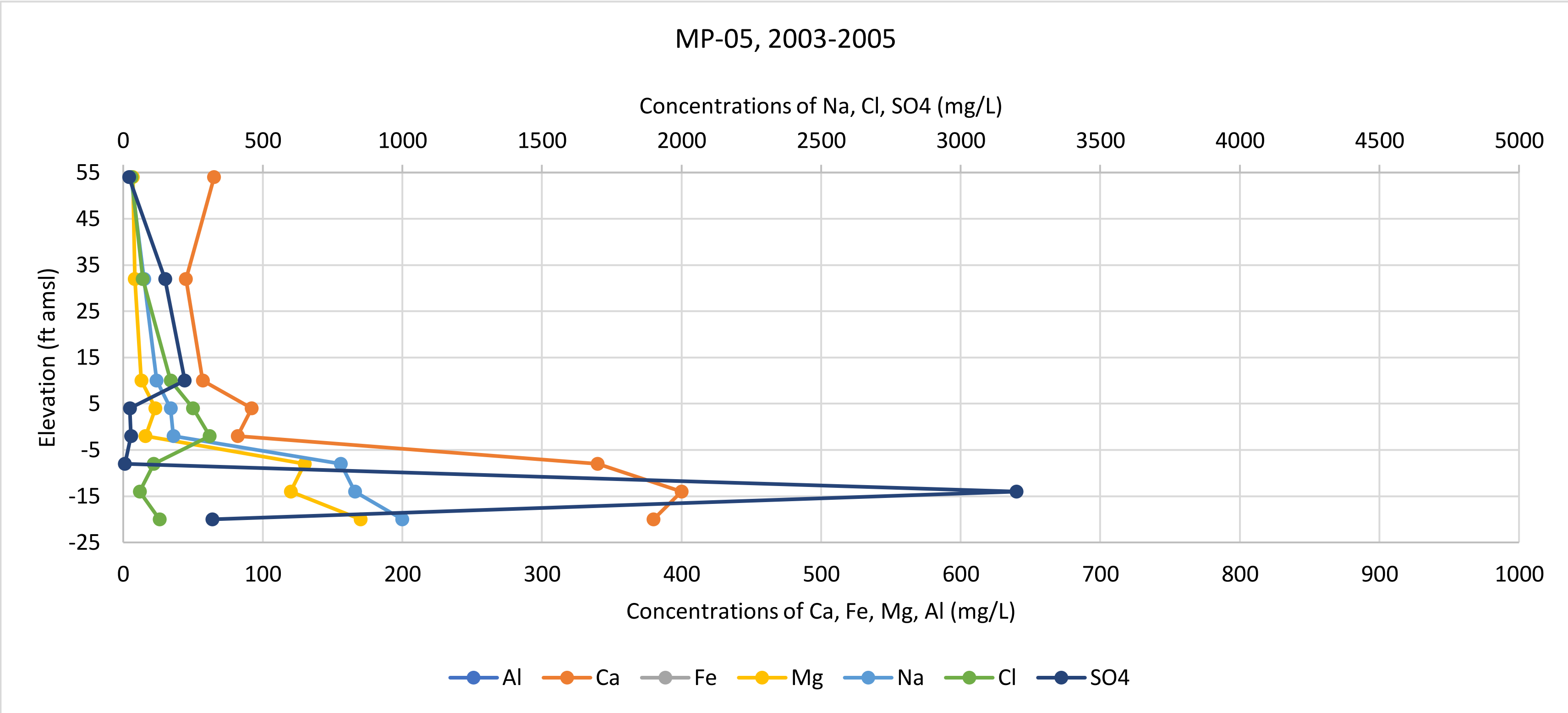


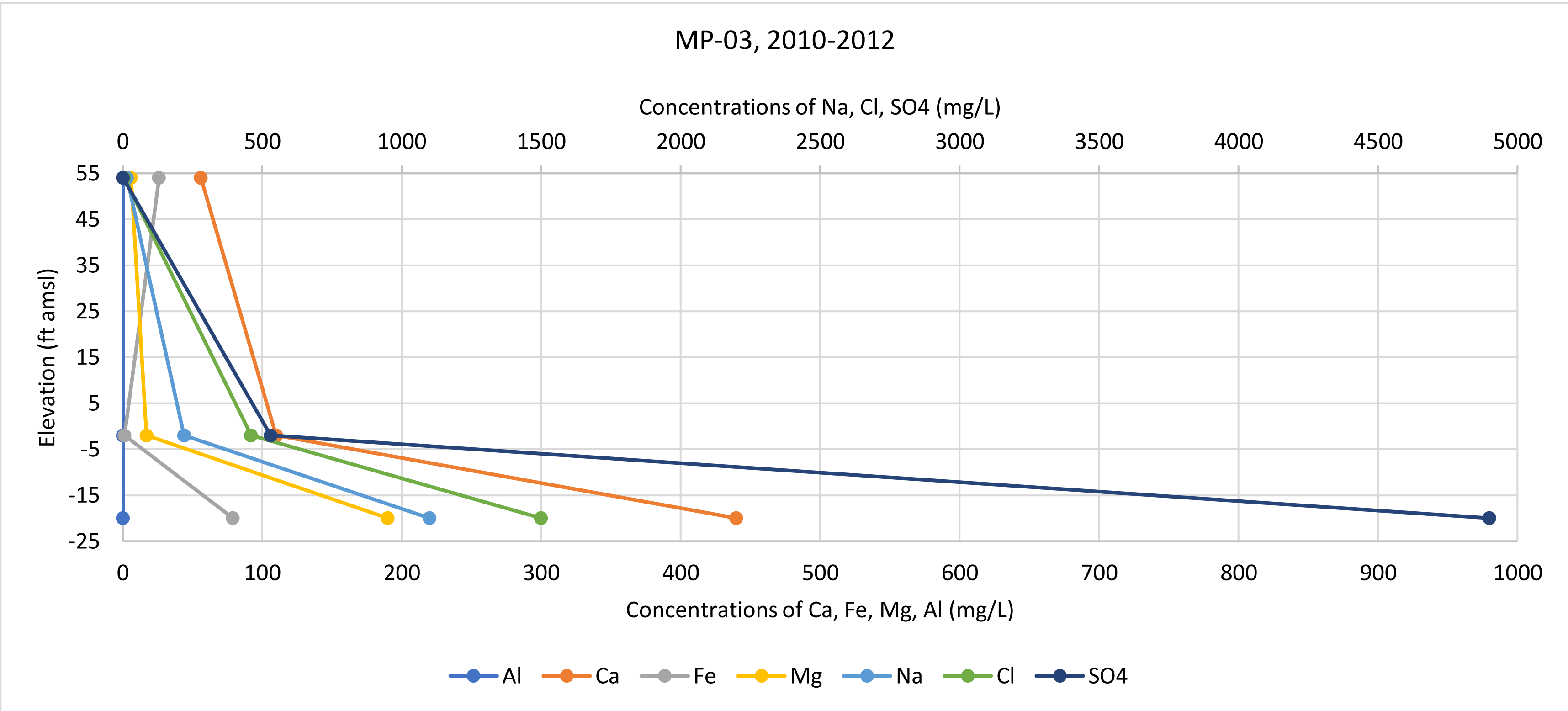
Attachment B
MP-04 Vertical Profiles
Olin Chemical Superfund Site
Wilmington, Massachusetts





Attachment B
MP-05 Vertical Profiles
Olin Chemical Superfund Site
Wilmington, Massachusetts





Attachment C
Mass Calculation Support
Olin Chemical Superfund Site
Wilmington, Massachusetts

Wells Used for Mass Calculations:

Overburden Plume - not including DAPL pools						
Area ID	Well ID	Top Elev.	Bedrock/ TOD Elev.	Zone Height (Ft)	NDMA (ng/L)	Notes
MMBW >11,000	GW-84D	4.4	-20.6	25	13,000	GW-84M screen bottom = upper bound
MMBW 5,000 - 11,000	GW-83D	-4.1	-40.8	36.7	8,500	GW-83M screen bottom = upper bound
MMBW 1,100 - 5,000	GW-85D	15.1	-5.9	21	4900	GW-85M screen bottom = upper bound
	GW-86D	15.9	-7.1	23	2700	GW-86M screen bottom = upper bound
	GW-87D		-25.7	20	1600	Rel. low conc.; assume 20' zone
	MP-5 #08		-18.5	20	1300	Rel. low conc.; assume 20' zone
	GW-62D	42.4	16.4	26	380	GW-62S screen bottom = upper bound
	GW-65D	64.4	-13.1	77.5	240	GW-65S screen bottom = upper bound
MMBW 110 - 1,100	GW-82D	56.2	20.2	36	330	GW-82S screen bottom = upper bound
	GW-63D	63.1	52.1	11	34	GW-63S screen bottom = upper bound
	GW-64D	64.1	20.6	44	75	GW-64S screen bottom = upper bound
MMBW 11 - 110	GW-103D	63.1	18.6	45	34	GW-63S screen bottom = upper bound
MMBW 1.1 - 11	GW-404D	56.7	26	31	2.3	GW-404M screen bottom = upper bound
PC > 11,000	GW-44*	64	42	22	25,000	GW-44S screen bottom = upper bound*
	GW-58*	68	42	26	24,000	GW-58S screen bottom = upper bound
	MP-3*	46	42	4	25,000	MP-3 #07 screen bottom = upper bound
PC 5,000 - 11,000	GW-45*	67.9	42	25.9	8,700	GW-45S screen bottom = upper bound
	GW-70*	68.2	42	26.2	9,900	GW-70S screen bottom = upper bound
	GW-59*	65.3	42	23.3	10,000	GW-59S screen bottom = upper bound
	MP-4 #12	56	31.5	24.5	10,000	MP-4 #13 screen bottom = upper bound
PC 1,100 - 5,000	GW-69D	67.9	46.1	21.8	4,000	GW-69S screen bottom = upper bound
PC 110 - 1,100	GW-71D	70.9	49.9	21	160	GW-71S screen bottom = upper bound
PC 11 - 110	GW-28D	79.2	69.2	10	40	GW-28D is closest MW (no wells in area)
PC 1.1 - 11	GW-21D	80.2	69.1	11.1	5.8	GW-21D is closest MW (no wells in area)
PE 5,000 - 11,000	GW-45*	67.9	42	25.9	8,700	GW-45D is closest MW (no wells in area)
PE 1,100 - 5,000	GW-10DR	77.3	56.3	21	4,600	GW-10S screen bottom = upper bound
	GW-55D	69.8	65.7	4.1	1,700	GW-55S screen bottom = upper bound
	MP-1*	57.9	54.9	3	1400	MP-1 #06 screen bottom = upper bound
	GW-42*	66	49.9	16.1	4300	GW-42S screen bottom = upper bound
	MP-2*	72.6	49.9	22.7	2400	MP-2 #15 screen bottom = upper bound
PE 110 - 1,100	GW-4D	68.5	63.3	5.2	830	GW-4 overlaps; GW-4 top = upper bound
	GW-202D	79.9	62	17.9	890	Top of water column = upper bound
	GW-408D	78	63	15	950	GW-408S midpoint = upper bound
PE 11 - 110	GW-3D	70.4	61.2	9.2	47	GW-3S screen bottom = upper bound
	GW-6D	76.5	60.5	16	87	GW-6S midpoint = upper bound
	GW-17D	74.2	66.6	7.6	56	GW-17S midpoint = upper bound
	GW-28D	79.2	69.2	10	40	GW-28S overlaps; GW-28S top = upper bound
	GW-29D	82	54.8	27.2	60	Top of water column = upper bound
	GW-31D	81	67.2	13.8	25	Top of water column = upper bound
	GW-34D	72.9	55.3	17.6	23	GW-34SR screen bottom = upper bound
	GW-51D	77.9	68.1	9.8	29	GW-51S midpoint = upper bound
	GW-52D	75.6	70.8	4.8	13	GW-52S screen bottom = upper bound
	GW-53D	81.5	74.3	7.2	110	GW-53S midpoint = upper bound
	GW-56D	76	61	15	55	Top of water column = upper bound
	GW-80D	70.6	61.2	9.4	110	GW-80S screen bottom = upper bound
PE 1.1 - 11	GW-21D	80.2	69.1	11.1	5.8	GW-21S overlaps; GW-21S top = upper bound
	GW-54D	78.9	71.3	7.6	7	GW-54S midpoint = upper bound
GW-413 1,100 - 5,000	GW-413D	74	55	19	1700	GW-413S concentration = upper bound
GW-413 110 - 1,100	GW-32D	77.6	60.7	16.9	590	GW-32S midpoint = upper bound

*For wells in DAPL pools, bottom elevation = top of DAPL pool elevation (reasonable maximum; see Table 1)

Attachment C
Mass Calculation Support
Olin Chemical Superfund Site
Wilmington, Massachusetts

Bedrock Plume						
Area ID	Well ID	Bedrock Elev.	Bottom Elev.	Zone Height (Ft)	NDMA (ng/L)	Notes
> 11,000	GW-62BR	16	-43	59	16,000	GW-62BRD midpoint = lower bound
East 5,000 - 11,000	GW-202BRS	53.2	-41.8	95	5,800	GW-202BRD concentration = lower bound
West 5,000 - 11,001	MP-4 #02	31.5	-70	101.5	5,700	Assume lower bound 10' below screen
	GW-406RD			77	1,800	GW-406BRS = upper bound, assume lower bound 10' below screen
1,100 - 5,000	MP-5 #03	-18.5	-31	12.5	4,300	Assume lower bound 10' below screen
	GW-61BR	33.6	-20.4	54	130	Assume lower bound 10' below bottom
110 - 1,100	GW-413BR	55	24	31	130	Assume lower bound 10' below screen
	GW-65BRDD	-21.2	-97.2	76	33	Assume lower bound 10' below screen
	GW-68BR	59.2	13.2	46	98	Assume lower bound 10' below screen
	GW-80BR	61.3	0.7	60.6	97	Assume lower bound 10' below screen
	GW-103BR	22.2	-35.1	57.3	37	Assume lower bound 10' below screen
primary 11 - 110	GW-405BRD	33	-165	198	15	GW-405BRS screen bottom = upper bound; assume lower bound 10' below screen
	MW-204BR	7.1	-8.2	15.3	3.5	Assume lower bound 10' below screen
	GW-404BR	26	-22.9	48.9	2.7	Assume lower bound 10' below screen
primary 1.1 - 11	GW-407BRD	17	-94.7	111.7	2.6	Assume lower bound 10' below screen
	M-03/L-02	--	--	100	18	
other 11 - 110	M-02/L-07E	--	--	100	12	
	M-01/L-06C	--	--	100	4	
	M-01/L-06D	--	--	100	3.6	
	M-03/L-02D	--	--	100	3.8	
	M-03/L-02F	--	--	100	1.4	
other 1.1 - 11	M-02/L-07	--	--	100	3.4	Assume 100' for residential wells in absence of any other data in area

Notes:
Residential wells used only if no monitoring wells available.
Ground surface assumed to be 90' MSL if elevation data not available.

Overburden Mass Calculation:

area (m^2) x thickness (ft) x 0.3048 m/ft x 30% = pore volume (m^3)

from Figure 7A

conversion

average thickness above for monitoring points

assumed porosity

pore volume (m^3) x concentration (ng/L) x $\underbrace{\text{1000 L/m}^3\text{ x µg/1000ng x mg/1000µg x g/1000mg}}_{\text{conversion}}$ = total mass (g)

from above

from average concentration in area

example: NDMA mass in deep overburden MMBW area >11,000 ng/L

10,530 m^2 x 25 feet x 0.3048 m/ft x 0.25 x 13,000 ng/L x $\underbrace{\text{1000 L/m}^3\text{ x µg/1000ng x mg/1000µg x g/1000mg}}_{\text{conversion}}$ = 10,267 g

area

thickness

porosity

concentration

conversion

Attachment C
Mass Calculation Support
Olin Chemical Superfund Site
Wilmington, Massachusetts

Bedrock Mass Calculation:

area (m^2) x thickness (ft) x 0.3048 m/ft x 1% = total pore volume (m^3)

from Figure 7B

conversion

average thickness above for monitoring points

High estimate for compentent bedrock porosity, OU3 RI Appendix H

pore volume (m^3) x concentration (ng/L) x $\underbrace{\text{1000 L/m}^3 \text{ x µg/1000ng x mg/1000µg x g/1000mg}}_{\text{conversion}}$ = total mass (g)

from above

from average concentration in area

example: NDMA mass > 11,000 ng/L:

17,125 m^2 x 59 feet x 0.3048 m/ft x 0.01 x 16,000 ng/L x $\underbrace{\text{1000 L/m3 x µg/1000ng x mg/1000µg x g/1000mg}}_{\text{conversion}}$ = 49 g

area

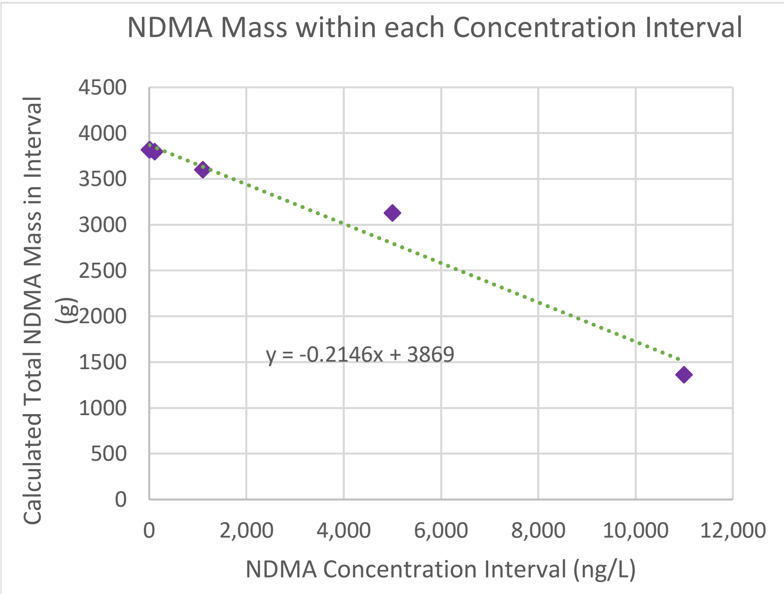
thickness

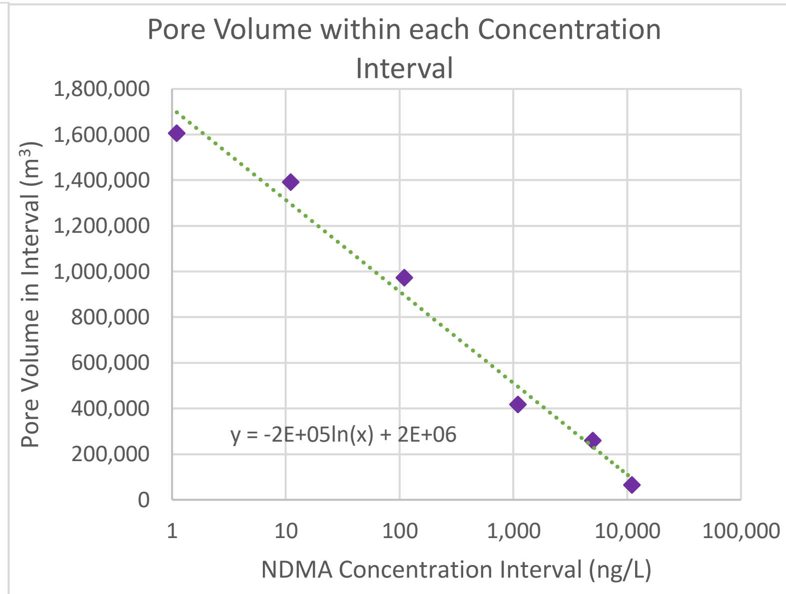
porosity

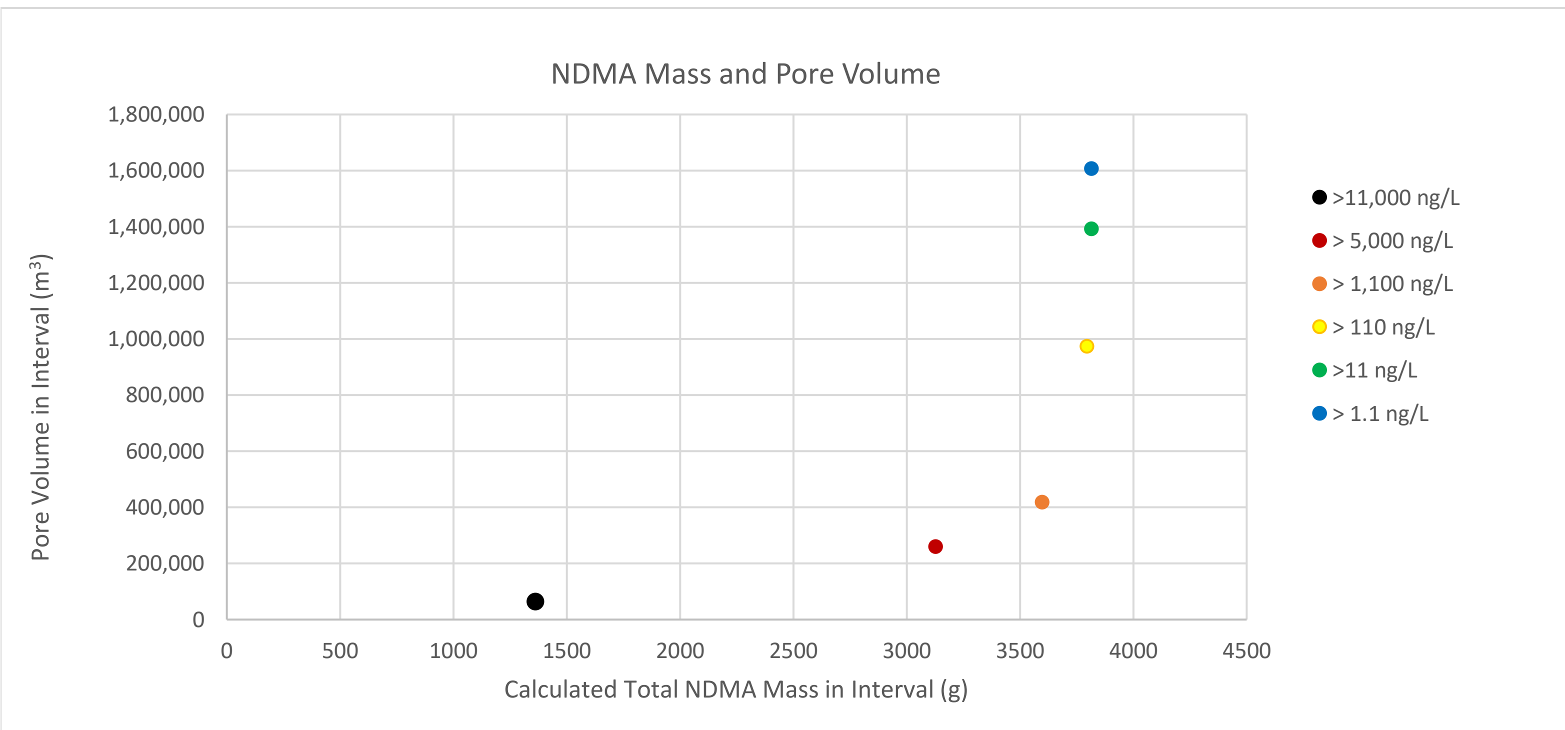
concentration

conversion

Attachment D: NDMA Mass Comparison - Overburden Plume
Olin Chemical Superfund Site
Wilmington, Massachusetts







Concentration Interval	NDMA Mass (g)	Total Pore Vol (m^3)
11,000	1361	64,655
5,000	3129	259,065
1,100	3599	417,386
110	3796	972,317
11	3817	1,391,751
1.1	3817	1,605,233

Notes:
1. Comparisons based on overburden plume groundwater values only; does not include DAPL mass.
2. Concentration interval based on the total area within each concentration contour, including separate hotspots.